DECISION SUPPORT AND RISK MANAGEMENT SYSTEM FOR COMPETITIVE BIDDING IN REFURBISHMENT WORK

By

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To

My wife, Pauline Goh, who has given me tremendous encouragement and support throughout the study and my parents who have waited patiently in Singapore whilst I pursued this study.

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Abstract

This study is concerned with the management of risks in competitive bidding for refurbishment work (lump sum contracts). It investigates the main difficulties and risks faced by contractors when they are making decisions in competitive bidding as a result of the general lack of information both inside and outside a contractor's organisation.

A decision support and risk management system model is developed which provides a systematic and objective approach to risk management in competitive bidding for refurbishment work. The model provides a framework whereby both quantitative (tender bid records) and qualitative (risk perception of contractors) information may be obtained to support the decisions of contractors during tendering.

The research adopts a combination of both Archival and Opinion research methodologies to build up two main databases consisting of tender bid records and information on the risk perception of contractors during tendering.

From the analysis, a decision support and risk management system is developed consisting of six modules namely: (i) Module 1 - Databases of tender bid records and Repertory grid data, (ii) Module 2 - General information of bidding characteristics, (iii) Module 3 - Contractor's analysis, (iv) Module 4 - Competitor's analysis, (v) Module 5 - Bidding models, and (vi) Module 6 - Risk management system.

This study has demonstrated that past tender bid records of contractors may be organised in a systematic way to provide invaluable strategic information to enhance the understanding of contractors with respect to their competitive bidding environments, their own bidding performance and the bidding behaviour of their competitors, thereby enabling contractors to manage risks more effectively and efficiently.

CHAPTER ONE

INTRODUCTION

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1.1 Introduction

This chapter provides the background to the research, identifying the common risks and uncertainties faced by contractors in competitive bidding. It highlights the general lack of information both inside and outside a contractor's organisation to support the decisions of management during competitive tendering. Particular emphasis was placed on the comparatively high risks involved when tendering for refurbishment contracts. It also provides a brief review of past work undertaken by various researchers aimed at helping contractors to manage risks in tendering. Against this background, the chapter sets out the main objectives of this research together with a discussion of various research strategies and methods and the selection of the research approach. The main contributions of this research are summarised and the structure of the thesis is outlined in the last section of this chapter.

1.2 Background of the study

Bidding for contracts is one of the most important activities for all contractors in the construction industry. Currently, competitive bidding is still a common method of awarding contracts to contractors in the industry. This method of work procurement has been widely accepted by many clients, particularly government organisations, as one of the most efficient and fair means of distributing work among contractors. Besides this, it also provides the most acceptable price (usually the lowest price) for a project in the prevailing market conditions.

Although competitive bidding is commonly practiced in the industry, it has a number of drawbacks. Tendering is a costly and time-consuming process. Very often, contractors must invest considerable effort and expense in preparing a bid and yet do not know the chance of success of their bids. As such, this expense is incurred through the submission of unsuccessful bids, which may cause contractors to suffer financial losses. In recent years, the cost of abortive tendering has been a major concern to many contractors, especially in the present competitive market. Many contractors understand that there is an urgent need to develop an appropriate bidding strategy to increase the effectiveness and efficiency of their bids.

In practice, contractors often encounter many difficulties when making a decision to submit a bid (tender adjudication). This is mainly attributed to the general lack of information both inside and outside the contractor's organisation to support the decisions of contractors during tendering. Often the information provided by consultants is inadequate or insufficient to enable contractors to assess the risks involved and price the tender accurately. Furthermore, not much information is available to enhance the understanding of contractors with respect to the bidding environment. This problem is further aggravated when tendering for refurbishment contracts which usually involve much higher risks in comparison to new build work due to its inherently uncertain and unpredictable nature. This difficulty is further compounded when clients impose stringent time constraint on contractors in the preparation of tender bids.

As a result, most contractors make decisions by relying on their intuition and experience. These decisions are often based upon subjective judgements of the decision-makers and could sometimes lead to undesirable consequences, such as incurring heavy financial loss or even bankruptcy. Although most contractors possess abundant competitive data based upon their own tender records, most of them fail to make full use of this information to support or improve their decision-making process. This is because most of the data are not being organised to make meaningful valuable strategic information available to contractors.

The subject of competitive bidding has attracted much interest among researchers and academics since 1956. Many researchers have made various attempts to improve contractors' understanding of the competitive market and of their competitors. Various prediction models were developed to aid contractors to determine the probability of winning a contract or to decide the optimum bid for different bidding situations. Many of these efforts have been concentrated on the development of mathematical probabilistic models which are aimed at predicting the probability of a contractor winning a particular contract. Unfortunately, most of these models have received very few practical applications in the industry. This is mainly attributed to the lack of consensus among bidding experts and the highly theoretical nature of most models. Another reason for their limited applications is that most contractors feel that it is unnecessary to adopt a statistical approach to bidding, and that their existing intuitive practices are adequate.

This research aims to provide a systematic and objective approach to risk assessment and management in competitive bidding for refurbishment work. It attempts to develop a framework whereby tender bid information may be organised to provide strategic information to support the decision-making processes of contractors during tender adjudication. Thus, this study adopts an Information Search approach to risk management in competitive bidding. The use of Information Search approach has been widely acknowledged and supported by many researchers such as Hakannson and Wootz (1) as being one of the most effective risk management strategies.

1.3 Objectives of the study

This study aims to provide an integrated and systematic approach to risk management in competitive bidding for refurbishment work. It proposes to develop a decision support and risk management system which will provide quantitative and qualitative information to support the decisions of contractors during tendering.

The main purpose of the decision support system is to determine strategic information which will enhance the understanding of contractors with respect to the competitive bidding environment in refurbishment work. This system adopts a structured framework to analyse the past tender bids of contractors so as to produce strategic information describing the bidding characteristics of various competitive environments. Besides this, the system also provides a mechanism for contractors to monitor their bidding performance and the relative performance of their firms against their competitors. Two bid prediction models are also incorporated into the system to enable contractors to predict the probability of success when submitting a tender bid.

The risk management system aims to identify major and pertinent risk factors involved in competitive bidding for refurbishment work under different types of bidding situations. Its main objective is to highlight significant characteristics of bidding situations which have undue influence on the risk assessment of contractors. Using a well established psychological technique called the Repertory Grid Interview, this system is able to identify the major risk perception constructs of contractors and establish relationships between various risk factors in competitive bidding for refurbishment work.

The main objectives of the study may be outlined as follows:-

a) To develop a decision support and risk management system which will increase awareness and enhance the understanding of contractors in competitive bidding for refurbishment work.

b) To provide a systematic and consistent risk management approach which will enable contractors to manage the risks involved in competitive bidding more effectively and efficiently.

The secondary objectives of the decision support and risk management system are as follows:-

a) To set up a database containing tender bid information of contractors in a computer system.

b) To identify and measure major bidding variables such as job type, job size, number of bidders, client type and job location so as to provide descriptive information about the bidding characteristics of refurbishment contracts.

c) To develop a suitable mechanism for contractors to monitor their bidding performance and that of their competitors.

d) To develop a bidding model for predicting the probability of success when submitting a tender bid under various bidding situations.

e) To highlight significant risk factors influencing the risk assessment of contractors during tendering.

f) To recommend appropriate risk management strategies for contractors in competitive bidding.

1.4 Research methodology

In order to determine the most appropriate research methodology, it is necessary to identify the main requirements of the proposed decision support and risk management system. As this study is mainly concerned with the setting up of an information search system (decision support system), the research methodology must be able to obtain adequate facts (tender bid records) in order to provide accurate information to contractors. This requirement demands the collection of a substantial number of tender bid records from contractors to obtain a statistically representative sample to describe the bidding characteristics of refurbishment work. As such, an Archival Research approach (2) is adopted whereby large quantities of data or factual information may be obtained and manipulated to analyse various bidding situations. This research method is a well established technique commonly employed to analyse accounting records such as serialised checks, receipts or purchase orders or salary records of employees. The main advantage of this method lies in its ability to access and manage a vast quantity of hard and very often factual information. Using this approach, a total of 2261 tender bid records for refurbishment contracts (lump sum contracts) were made available through the Builders' Conference in London for the study.

As for the risk management system, an Opinion Research methodology is used because this approach permits the collection of information describing the risk perception of contractors. The salient advantage of this technique is its ability to capture people's impressions about themselves, their environment and their responses to changing conditions. Thus, this method is most suitable for measuring the risk perception of contractors under different competitive bidding situations. Besides this, Opinion Research has numerous secondary advantages such as simplicity of administration, ability to sample a large population and considerable opportunities to analyse the data through various statistical procedures.

Thus, the main research methods adopted for this study consist of a combination of Archival and Opinion research. A detailed description of each of these research methodologies is provided in chapter seven. Major advantages and limitations of the adopted research methods were also highlighted including an explanation of various precautions taken by the researcher to improve the accuracy and reliability of the proposed decision support and risk management system.

1.5 Findings of research

As will be discussed in chapter ten, this research has provided an integrated and systematic approach to risk management in competitive bidding for refurbishment work. It has identified the common problems faced by contractors due to the lack of information when they are deciding to submit a tender. The proposed decision support and risk management system has proved to be an effective risk management tool by increasing the awareness and understanding of contractors during tendering. It has enabled contractors to obtain strategic information about their competitive environment and the bidding behaviour of their own firms and their competitors.

Besides this, the system has also highlighted significant risk factors affecting the risk assessment of contractors during tendering in various bidding situations. This has increased the knowledge and understanding of contractors and at the same time, has provided guidance to enable contractors to focus their efforts on managing risks more effectively and efficiently. The risk management system also shows how the risk perception of contractors differs under different bidding situations or circumstances. Significant relationships between the risk perception of individual contractors and various risk factors are also determined. The results of this analysis have significantly enhanced the understanding of contractors.

This research has shown that it is possible to use bidding and risk management theories to develop a framework for contractors to manage risks more effectively and efficiently in competitive bidding. Records of the bidding performance of contractors may be organised in a meaningful way to facilitate the decision-making process of contractors during tendering. This method also provides a more consistent and objective approach to managing risks in competitive tendering.

Thus, the main benefits and contributions of this research may be summarised as follows:-

a) It has increased the understanding of contractors with respect to the unique characteristics of refurbishment work and its competitive tendering system (lump sum contracts).
b) It has identified the main risk factors commonly encountered by contractors under different bidding environments and has recommended suitable risk management strategies for handling these risks effectively and efficiently.
c) It has demonstrated how risk perception of contractors varies under different competitive conditions and has determined the underlying reasons for such variations.

d) The study has provided an objective approach whereby past tender records may be utilised through proper organisation to improve the decisions of contractors in competitive bidding.

In conclusion, this study has provided a new insight into the management of risks in competitive tendering for refurbishment work and has contributed towards reducing the risks faced by contractors in competitive tendering.

1.6 Structure of the thesis

This thesis has been organised in a logical and readable manner so as to enable readers to appreciate the thoughts of the researcher in the development of the proposed decision support and risk management system. The thesis is organised into ten chapters. The first five chapters provide a comprehensive review of literature relating to the characteristics of refurbishment work, decision and risk management theories and past bidding models. The next three chapters describe the design and development of the proposed decision support and risk management model including the description of research data and methodology. The last two chapters concentrate on the analysis of the results of the research and provide a summary of the main findings of the study. A brief description of each chapter is given below:-

Chapter one addresses the common risks and uncertainties faced by contractors when tendering for refurbishment work. It also states the main objectives of this research and provides a discussion on the available research strategies and methods.

In chapter two, a comprehensive review of the nature and characteristics of refurbishment work is presented. This review focuses on the unique problems and risks commonly encountered by contractors in the execution of refurbishment work. Besides this, it also highlights the estimating and tendering procedures commonly practiced by refurbishment contractors in the United Kingdom construction industry.

Chapter three identifies the main sources of risks involved in competitive bidding for refurbishment contracts (lump sum contracts). Various risk management strategies, tools and techniques are discussed in relation to their potential application in the management of risk in competitive bidding for refurbishment work. A brief review of decision-making theory is presented, with particular emphasis on the decision-making process of contractors in competitive bidding.

The theoretical concept of Personal Construct Theory is described in chapter four together with the use of the Repertory Grid interview technique for measuring the risk perception of people. This chapter also discusses the logical procedure commonly adopted for the elicitation of personal constructs of people.

Chapter five provides a literature review of the past bidding models of various researchers. It discusses the assumptions made by various bidding experts and summarises the main findings of all these researchers. The main limitations of these models are also highlighted, explaining the underlying reasons for the scarcity of applications of bidding theory in the construction industry.

Chapter six outlines the basic concepts of the decision support and risk management system. It describes the conceptualisation process, design approach and construction of the proposed system. It also highlights the main information requirements of contractors in competitive bidding and explains how the proposed system is able to fulfill the needs of contractors in managing risks more effectively and efficiently.

The main research methodology is discussed in chapter seven including the selection and justification of the research approach adopted. The reasons for selecting various research instruments are highlighted together with the justification of the sample size adopted.

Chapter eight provides a detailed description of the tender bid data used in the proposed system. It describes the collection, collation and coding methods adopted to facilitate the development of the information system. Besides this, it also explains the quantitative and statistical measures used to describe the bidding characteristics of refurbishment work.

In chapter nine, the main analysis of the results is described and the findings of various modules of the decision support and risk management are displayed in their respective sections.

Finally, chapter ten summarises the main findings of this research and its contribution to risk management in competitive bidding. It also provides recommendations for further research into this area.

CHAPTER TWO

LITERATURE REVIEW - CHARACTERISTICS OF REFURBISHMENT WORK

CHAPTER TWO

CHARACTERISTICS OF REFURBISHMENT WORK

2.1 Introduction

This chapter describes the growing market of refurbishment work in the United Kingdom construction industry. It highlights the main contributory factors influencing the unprecedented growth in the refurbishment, rehabilitation, modernisation and improvement of various types of buildings during the last fifteen years. The unique characteristics of refurbishment work are also described with particular emphasis on their influence on the estimating, tendering and construction processes. The last section of this chapter provides an overview of the estimating and tendering procedures adopted by contractors for refurbishment work.

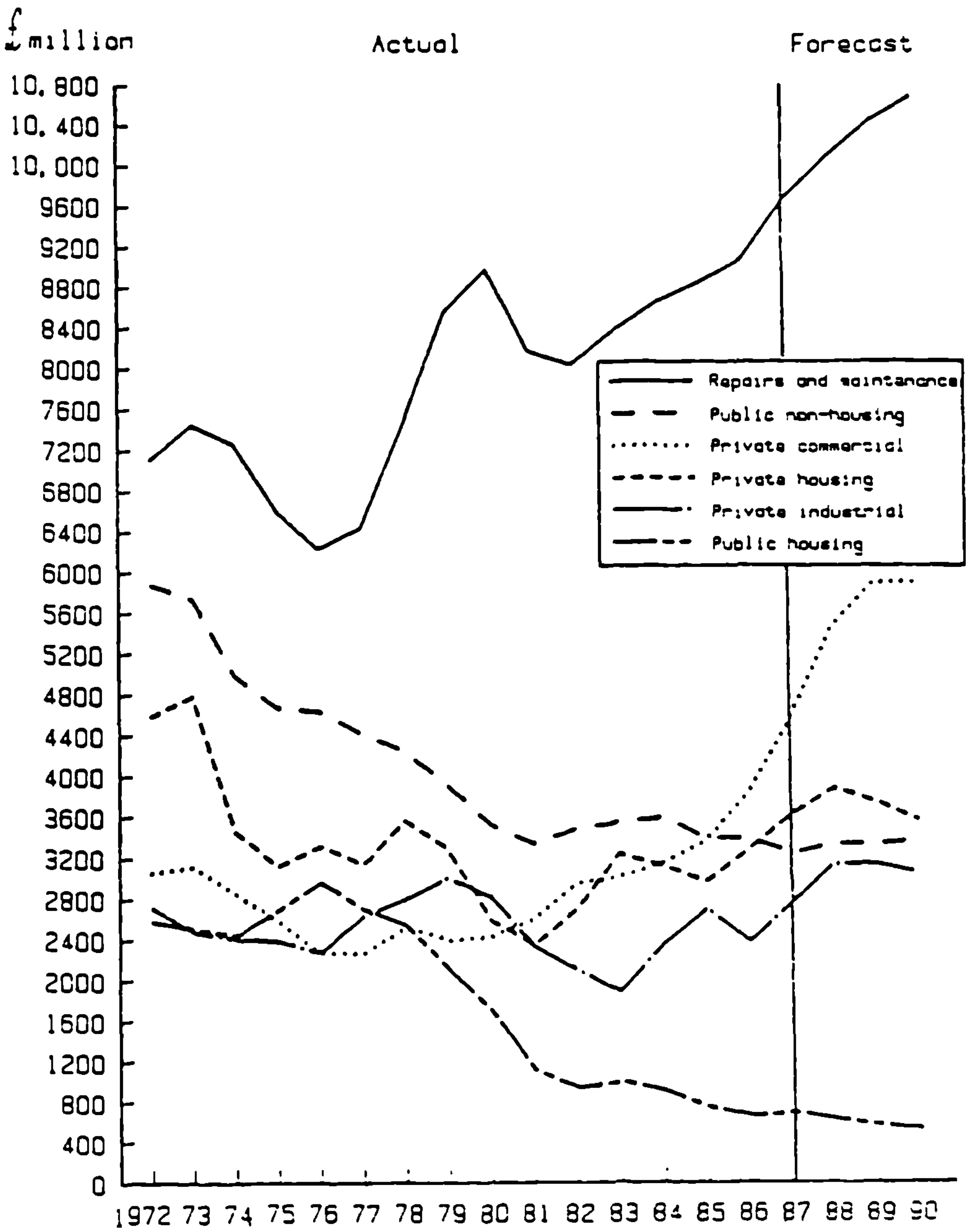
2.2 Growth of refurbishment work in the construction industry

In the last fifteen years, the value of refurbishment and modernisation work has increased significantly in the United Kingdom construction industry. Dramatic changes have occurred in the refurbishment market, particularly in the period between 1977 and 1980 when the workload of repair and maintenance work rose rapidly accounting for about 37% to 40% of the total construction output as illustrated in figure 2.1. Since then, the proportion of maintenance and repair work has remained around 40% and thus has been contributing significantly to the total output of the construction industry.

Although, there are no official statistics available to indicate the exact size of the refurbishment market, the Department of Environment (DOE) publishes statistics indicating the value of repair and maintenance work in the construction industry. According to the Department of the Environment, repair and maintenance work includes all improvement work carried out on existing housing but excludes improvement work to non-housing sectors which is classified as new-build work. It also excludes the conversion of industrial and commercial buildings through refurbishment to housing units which is also considered as new-build work.

Figure 2.1 : Construction output in the United Kingdom

(Source: Construction forecasts 1988-1989-1990, NEDO)



There is a distinct difference between repair and maintenance work and refurbishment work. Repair and maintenance work usually refers to "work undertaken in order to keep or restore every facility, i.e. every part of a site, building and contents to an acceptable standard." (BS 3811, 1964). On the other hand, refurbishment work encompasses a wider range of work which includes the repair, conversion, alteration, modernisation, improvement and extension of a building or area which is previously unusable or unsuitable to a state where it becomes usable at a standard acceptable to the community.

Thus, there is effectively no accurate measure to determine the actual value of refurbishment work in the industry. However, the DOE's statistics on repair and maintenance work are generally used by practitioners as a yardstick for monitoring trends in the refurbishment market. Although this provides a satisfactory yardstick for the housing market, it is a poor indicator for the industrial and commercial sectors. Furthermore, this figure does not take into account the value of "DIY" work carried out by many house owners in the so called "black economy". As such, the actual value of refurbishment work is probably much larger due to the unrecorded statistics from the "black economy".

2.3 Factors influencing the growth of refurbishment work

The growth of the refurbishment market has been motivated by a number of factors which are related to the political, economic, social and technological forces of the environment. Demand for refurbishment work has increased significantly as a result of these market forces which are explained in the following sections.

2.3.1 Sociological changes

In the last 40 to 50 years, the United Kingdom construction industry has undergone many changes and much restructuring. As a result of the Second World War, there were severe shortages of housing. Most maintenance work was postponed while much effort was concentrated on the provision of new buildings. By the mid 1970's, the demand for new buildings was met and more emphasis was placed on the repair, maintenance, refurbishment and improvement of the existing stock of buildings. This has greatly increased the refurbishment activities of the construction industry thus increasing the overall contribution of the refurbishment sector to the total construction output.

Increasing pressure from social groups to maintain and upkeep communities together as against slum clearance have also contributed much to the increased workload of the refurbishment industry. For instance, the strong conservation and preservation movement towards "conservation" by the English Heritage (formerly known as Historic and Monument Commission) has provided much impetus to the rapid growth of refurbishment and rehabilitation activities. Many buildings have been listed to be of historical value and are only permitted to be refurbished instead of being re-built, thus contributing to the demand for refurbishment work.

Another factor which has contributed significantly to the growth of refurbishment work, particularly in the modernisation of shopping and retail centres, is the changing taste and preferences of consumers. There is a growing tendency for consumers to drift from the traditional corner shop towards town centre or major superstores. This change of shopping habits has sparked off a major boost in the refurbishment of many retail and shopping developments which were originally built for a different style of shopping activities. Many developers are compelled to upgrade and modernise their shopping premises in order to attract shoppers.

The gradual decline in average household size together with the rapid rise in house prices, especially in London, has also created considerable demand for the refurbishment of residential properties particularly the conversion of large flats into smaller units.

Thus, the above social developments and changes have created a sizeable market for the refurbishment of residential, industrial, commercial and retail buildings in both the private and public sectors over the years.

2.3.2 Political changes

The refurbishment industry has also been greatly influenced by changes in the political conditions of the United Kingdom. Under the Conservative government, the economy has been re-structured quite drastically over the last ten years. Various old forms of manufacturing and sea port activities have declined drastically. Consequently, this has created a stock of redundant industrial buildings which now require refurbishment work either to reinstate them or convert them for other uses such as residential or commercial purposes.

In recent years, increasing importance has also been placed on renewing and regenerating existing assets (building stocks) of the country. As observed by Hillebrandt (1), many buildings especially those located in the inner cities have been under-utilised, wrongly utilised or have become dilapidated. These run-down geographical areas and buildings tend to generate or exacerbate social problems such as vandalism. A number of new initiatives have been undertaken both by the government and the private sector to regenerate these areas.

As part of their continuing effort to regenerate existing building assets, the government had also launched an "Urban Programme" in July 1981. Under this scheme, all local authorities were requested to develop schemes for improving the physical environment and ensuring that all local services and amenities were upgraded to fulfill the social needs of the local communities in the urban areas. Private sector involvement was also encouraged and partnerships were formed between the government and the private sector to undertake major refurbishment projects. Development grants were also introduced to encourage the refurbishment of industrial and commercial properties particularly in regions of high unemployment.

In the housing sector, the need for improvement and rehabilitation is well documented in the English House Condition Survey 1981 (2) which states that "there are 1.1 million dwellings unfit to live in; 0.9 million dwellings which lack of one of the five basic amenities and 2 million dwellings requiring repairs in excess of £7000". Improvement, repair and maintenance grants were provided by the government through local authorities to provide incentives for house owners to rehabilitate their dwellings. Thus, the government has been one of the main motivating forces behind the increasing demand for refurbishment work.

2.3.3 Technological changes

Technological advances such as office automation and computerisation together with the increased image consciousness of many enterprises have put many developers under considerable pressure to update their offices in order to achieve a satisfactory occupancy rate and secure a reasonable return on rental rates. Many office buildings which were built in the 1960's and 1970's are not suitable for incorporating these modern communication systems. Consequently, extensive upgrading work is required to improve the conditions of these offices so as to meet the new requirements of tenants.

2.3.4 Economic changes

As emphasised by Hillebrandt (1), the demand for the construction industry is highly sensitive to the general economic conditions. In a buoyant market with growing gross domestic product, high employment rate and a satisfactory balance of payments position, the standard of living will tend to rise and government will be able to increase its public expenditure to improve the services of the community thus boosting demand for construction work. On the other hand, in times of a depressed market and soaring interest rates, demand for construction work, particularly refurbishment and improvement work will be drastically reduced. Public expenditure will be severely cut and many property owners will also tend to postpone any refurbishment or improvement work to their properties thus dampening demand for refurbishment work.

2.3.5 Health and safety standards

In recent years, various stringent restrictions and regulations have been imposed by the government to ensure the health and safety of occupants in buildings. The introduction of these regulations has resulted in many buildings failing to comply with these new requirements. This applies particularly to buildings which were constructed in the early 1960's and 1970's. Most of them fail to meet the minimum required standards in terms of fire safety, energy conservation, heating and ventilation. Thus, the imposition of new regulations has also prompted the refurbishment of many existing buildings.

2.3.6 Ageing stock of buildings

The ageing of the existing stock of buildings is another contributory factor to the growth of the refurbishment market. There are many buildings built in the early 1900's which either lack basic amenities (to the present standard of living) or have run into disrepair. The number of dwellings which were considered unfit for habitation, as surveyed by the English House Condition Survey 1981 (2) and discussed earlier, exceeds a million. The declining condition of these buildings has exerted considerable pressure on both the government and house-owners to carry out rehabilitation work. Various incentive schemes such as improvement grants were provided by the government to encourage house owners to upgrade and improve their dwellings.

Besides residential properties, there are also many existing industrial buildings which are either in a dilapidated condition or have been designed for purposes for which they are no longer required. These buildings also need substantial refurbishment and improvement work to upgrade them to acceptable standards. As discussed earlier, the government has also introduced various schemes to regenerate these properties.

2.3.7 Benefits of refurbishing

There are many benefits of refurbishing an existing building as compared to the construction of a new building. Refurbishment provides a cheaper alternative and usually requires a shorter completion period which is of paramount importance to many clients, particularly those in the commercial sector. Besides this, it also enables clients to continue their business operations during the entire refurbishment period. Another advantage of refurbishing is that it avoids the lengthy process of obtaining planning approval. Furthermore, the refurbishment of an existing building is not constrained by stringent plot ratio restrictions (which are imposed on new-build work) especially in inner city areas. Thus, the enormous benefits of refurbishment work have also provided much impetus to the growing trend towards it.

2.3.8 Others

There are many other factors which have contributed to the rapid growth of the refurbishment market in the construction industry. The increasing requirements and awareness of tenants of their choices for premises have placed considerable pressures on developers and property owners to upgrade and improve their properties, especially in offices. Developers are also more aware of the cost-in-use of their buildings and thus hope to improve their premises to achieve low maintenance and running costs, a satisfactory working environment, flexibility and adaptability of internal space and attractiveness to tenants.

2.4 Definition of terms in refurbishment work

The term "refurbishment" has been commonly adopted by many practitioners, researchers and institutions to include various forms of construction work carried out on existing buildings or areas. Norman Douglas (3), director of Costain Construction Limited (refurbishment division), defined refurbishment as:-

"a process of changing a building, or indeed an area previously unusable or unsuitable, to a condition where it becomes usable at a standard acceptable to the community. It may involve substantial change of use. This also includes improvement which is less dramatic and does not usually involve change of use. Repair and maintenance also enters into this section of the building industry, which implies the continuing up-keep of building stock to existing standards."

The Chartered Institute of Building in its code of estimating practice supplement number one (4) defines "Refurbishment and Modernisation" as:-

"The alteration of an existing building designed to improve the facilities, re-arrange internal areas, and/or increase the structural lifespan without changing its original function."

Another definition as put forward by George Hall (5) is as follows:-

"Refurbishment refers to the process of repair, conversion and alterations of existing buildings to permit their re-use for various specified purposes."

According to George Hall, refurbishment work may be generally categorised into the following main types:-

a) **Alteration** - This is work which is carried out to change the structure of a building to meet new requirements. For instance, changing the internal layout of a building.

b) **Adaptation** - This is work which is carried out to accommodate a change in use of a building.

c) **Extension** - This is work which is carried out to increase the floor area of a building and includes both horizontal and vertical extensions.

d) **Improvement** - This is work which is carried out to bring a building and its facilities up to an acceptable standard.

For the purpose of this study, refurbishment work is considered to encompass a wide range of work such as rehabilitation, alteration, adaptation, extension, improvement, conversion, modernisation, fitting out and repair, which is undertaken on an existing building to permit its re-use for various specified purposes. This definition does not include repair and maintenance, which is normally carried out on a continuing routine basis to up-keep a building to an acceptable standard and consists of work such as daily cleaning, periodic painting or other emergency maintenance work.

2.5 Characteristics of refurbishment work

Every building has its own unique problems and difficulties. However, these problems are more acute when carrying out refurbishment work in existing buildings or adjacent to other buildings especially when tenants are in occupation. Unlike new-build, refurbishment work possesses certain unique characteristics which have caused much difficulty and uncertainty to contractors particularly during the estimating, tendering and construction processes. These characteristics may be broadly classified into five main categories as discussed below.

2.5.1 Labour

a) **Small work packages** - Refurbishment work often consists of small work packages. It usually includes "cut and carve" work on different parts of a building such as forming openings for doors and windows, providing ducts or trunking for services or replacing defective parts of a building. These work packages are often uneconomical and also pose much difficulty to contractors in allocating their labour resource to achieve maximum productivity.

b) **Restriction of site access** - Site access is often restricted especially when carrying out refurbishment work in urban areas. As a result, the working conditions on site are severely constrained, thus increasing the labour hours needed and also lowering labour productivity. For instance, travelling time of workers may be increased and more difficulty will be also encountered in the movement of labour forces from one work position to another.

c) **Restriction of working hours** - In refurbishment work, clients may impose certain working hours on the contractor especially when work is being carried out in premises where tenants are in occupation. The extent of restrictions usually depends on the type of occupants and their sensitivities to noise, dust and working operations disturbances. Sometimes, contractors are only permitted to work during specified hours of a day or at certain time period intervals. For example, in refurbishing school buildings, contractors may be restricted to work on weekends or school holidays for reasons of safety and health to the occupants. Such restrictions may cause much disruption to the continuity of work and also increase the cost of work as overtime working is required.

d) **Labour intensive** - Due to the nature of work (small work lots) and restricted access, it is often difficult and uneconomical to utilise many mechanical plant and power tools. The selection of plant is also limited thus making refurbishment work more labour intensive as compared to new-build work.

e) **More dangerous** - Refurbishment work is also more dangerous due to its inherently uncertain nature. This characteristic is more apparent in the refurbishment of historic buildings with a high content of demolition work or when the work involves the removal or stripping of asbestos, lead or other toxic products. Very often, it is difficult to determine the exact condition of a building until work begins and thus there is a higher probability of encountering unexpected conditions which may sometimes be dangerous.

f) **Matching of traditional skills** - The matching of refurbished work with existing work is a unique feature of refurbishment work and involves special skills and attention. This is particularly so when refurbishing expensive or priceless ornamental fittings or finishing in buildings of high historical value. In the present tight labour market, contractors often encounter much difficulty in employing skilled labour especially in traditional skills such as masonry, glazing and joinery work. The problem of matching refurbished work with the existing building components is well emphasised by a refurbishment specialist (6) as follows:-

"It's no secret that the business of blending new construction with old holds a unique stock of technical booby-traps"

2.5.2 Materials

a) **Storage and handling of materials** - Site constraints also cause many problems in the storage and handling of materials. Inadequate site storage space usually restricts the amount of material which can be delivered to site thus increasing the frequency of deliveries. This problem is further compounded when working in inner city areas due to strict traffic regulations which only permit loading and unloading of materials at specified times and places. As a result, materials have to be transported to the site in small quantities (subject to site storage space) at specified times. This not only increases the cost of transportation but also requires more management effort to plan and co-ordinate the flow of materials on site. The handling and distribution of materials to various work positions (different parts of a building) may also cause much difficulty especially in confined sites, and may entail considerable amounts of double handling.

b) **Matching of materials** - Problems may also arise in matching new materials with existing materials in the refurbished building. This problem is more acute in the refurbishment of listed buildings which often possess features of historic importance and may be built with materials which are no longer in production. Another common difficulty encountered by contractors is the replacement of brickwork in old buildings which were constructed of bricks in imperial sizes while new bricks are manufactured using metric measurements.

c) **Economies of scale** - Due to the characteristic of small work packages comprising different trades, materials are usually purchased in small quantities and thus no benefit of bulk purchase could be achieved by contractors.

2.5.3 Plant

a) **Limited selection of plant** - As discussed before, the problem of limited site access imposes many constraints on the selection of mechanical plant. However, in recent years many plant manufacturers have produced a variety of "small sized" machines which are specially designed to work in confined site conditions.

b) **Productivity of plant** - It is also difficult for plant to achieve their optimum productivity levels in such working conditions. Movement and manoeuvrability of plant is severely restrained thus reducing productivity.

c) **Standing time of plant** - There is a higher proportion of standing and idling time of machines such as hoists or scaffolding especially when there are restrictions on working hours. Plant may have to be left on site (non-productive) when the proposed work has to be carried out in stages or at certain time intervals.

2.5.4 General facilities

a) **Protection** - Generally, refurbishment work requires more protective measures and precautions to be taken as compared to new-build work. This is because it is performed in existing buildings or in proximity to other buildings and sometimes may have to be undertaken with tenants in occupation. Provisions must be made to protect existing buildings, the general public, occupants of buildings and the refurbished work. Temporary work may be necessary to strengthen existing or neighbouring structures. Noise and dust protective screens may be required to ensure the safety and comfort of the general public and occupants of the buildings. In certain circumstances, special precautions must be taken to protect sensitive office equipment and installations such as computers. In addition, the contractors must also protect the newly refurbished work to avoid damage or pilferage.

b) **Provision of temporary services** - When refurbishing buildings which are in operation, existing services must be maintained either through relocation or the provision of temporary services. This may present difficulties especially when there is limited space on site.

c) **Security** - This is an increasing problem particularly when working in highly sensitive premises such as the premises of High Commissions, Embassies or government offices. Added precautions must be taken to ensure that these premises are properly locked and secured at the end of each working day. The pilferage of building materials is also widespread especially in remote areas such as council estates.

d) **Safety and welfare** - The stringent regulations concerning safety and welfare of both the public and construction workers also cause grave concern to refurbishment contractors. Strict compliance to the Health and Safety Act 1974 must be adhered to particularly in the handling of hazardous and toxic products such as asbestos and lead. This point is further emphasised by Claude Brown, past president of the National Federation of Demolition Contractors (NFDC) (7) as follows:-

"Nobody used to worry unduly about the removal of asbestos and lead paint, but things have changed. Now you have got to take special precautions when you're

removing lead products, and you need a licence to handle asbestos."

2.5.5 Management

a) **Planning, co-ordination and supervision** - Refurbishment requires a more flexible approach in its planning and co-ordination as it is less predictable (higher element of uncertainty) unlike new-build. The sequence of work is less uniform and sequential as in new-build work and often involves the simultaneous working of multiple trades at different parts of a building. Thus, it is more difficult to plan the flow of work to attain high productivity due to the nature of the work, problems of site constraints, restrictions on work hours and additional necessary precautions. The co-ordination and supervision of work is also more problematic as workmen are scattered throughout the building or in isolated areas.

b) **Crisis management** - Due to its inherent uncertain nature, refurbishment work invariably involves certain elements of "crisis management" and thus demands higher management and supervisory skills. More management resources inputs are required to ensure the smooth running of the project. Besides this, additional communication and public relation skills are needed to maintain good working relationships with clients and consultants to avoid unnecessary disputes.

c) **Contractual obligations** - Refurbishment work is renowned for exceeding project duration due to its high degree of uncertainty. Very often, a "time is of the essence" clause is included in the contract thus making the contractor liable if there is any delay in the project. Consequently, management must plan the work programme more carefully and accurately, allowing sufficient contingency provisions for unexpected circumstances. There is also a higher proportion of remeasurement work in refurbishment as many items of work are usually not possible to ascertain until work begins. As a result, there are always many provisional items which may lead to contractual dispute.

2.6 Estimating and tendering procedures in refurbishment work

The Code of Estimating (8) as published by the Chartered Institute of Building provides an authoritative guide to good practice in estimating for building work. In 1986, the institute published a supplementary guide to the code of estimating practice for refurbishment and modernisation work (4) taking into considerations the unique characteristics of such work. As defined by the Chartered Institute of Building, *"Estimating is the technical process of predicting cost of construction"* while *"Tendering is a separate and subsequent commercial function based upon the net cost estimate."*

The detailed procedure for the estimating of and bidding for building work is described in the code of estimating practice. Figure 2.2 provides a flow chart displaying the process of preparing a tender. Basically, the preparation of a tender in refurbishment work is similar to new-build work and involves the following main steps which are outlined as follows:-

a) Invitation to tender

- Receipt of invitation to tender from client.

b) Decision to tender

- Receipt of tender documents.
- Completion of preliminary / tender enquiry form.
- Inspection of tender documents.
- Checking information required for estimating.
- Checking conditions of contract.
- Considering work load (estimating department) and time-table.
- Considering type of work and resources needed.
- Management decision to tender.

c) Project appreciation

- Management of estimate.
- Ensuring all tender documents are received.
- Time-table for the production of cost estimate and tender.

- Thorough examination of tender documents.
- Prime cost, provisional sums, daywork and contingency.
- Production of tender programme and method statement.
- Site visit.
- Visit to consultants.

d) Enquiries and quotations

- Preparation of documents for inquiring purposes.
- Enquiries.
- Quotation analysis.

e) 'All-in-rates' and unit rates

- Establishment of 'all-in-rates'.
- Receipt, analysis and selection of quotations.
- Establishment of net unit rates.

f) Completion of cost estimate

- Considering nominated suppliers and sub-contractors.
- Considering preliminaries and project overheads.
- Considering firm price allowance or increased cost allowance.
- Review and finalise cost estimate.

g) Estimator's report and adjudication

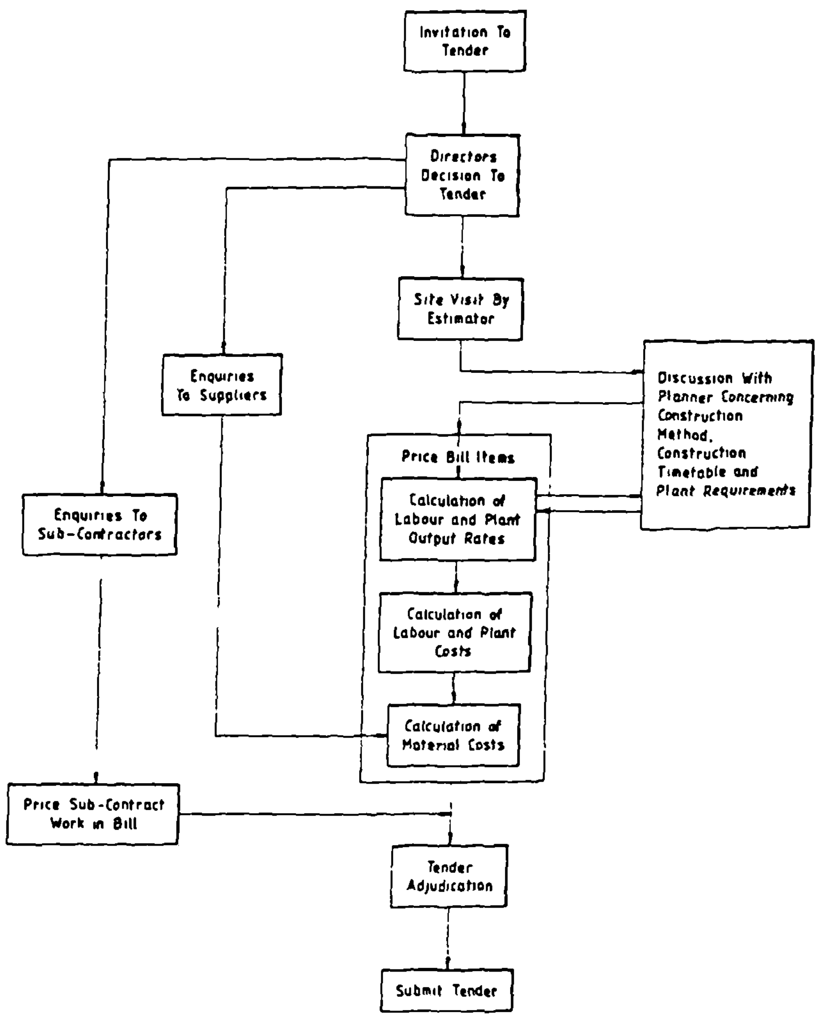
- Estimator's summary, analysis and report.
- Adjudication.
- Submission of the tender.

The tender preparation process begins with the decision to tender. Once the management decides to submit a tender, an estimate programme will be prepared for monitoring the estimating process. This is followed by the project appreciation process whereby tender documents are examined and enquiries are made to consultants in order to derive a method for carrying out the proposed work. Thereafter, the cost of work is determined. The cost estimating process includes the establishment of all-in-rates of labour, material and plant, build-up of unit rates, calculation of preliminaries and overheads and obtaining quotations from sub-contractors and suppliers. A site visit will be carried out to determine the working conditions and thereafter the cost estimate will be prepared together with the estimator's report for tender adjudication. During tender adjudication, the management will add in the profit, general overheads and the necessary risk allowance to arrive at the tender bid. The amount to be added will normally depend on considerations such as the workload of the firm, the assessment of risks involved, the likely level of competition and the desirable profit margin of the firm.

Figure 2.2 : Procedure for estimating and tendering

(Source: Bennett et. al., Construction cost data base, 1st report,)

(Property Services Agency, Dept. of Environment, 1979).



CHAPTER THREE

RISK AND DECISION-MAKING IN COMPETITIVE BIDDING

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3.1 Introduction

This chapter provides a brief review of the concept of risk and defines it within the context of the construction industry. It discusses the debate among researchers with regard to the distinction between risk and uncertainty and adopts the view that both risk and uncertainty are synonymous when making decisions in the turbulent and unpredictable construction industry. Major sources of risk in estimating and tendering are identified with particular reference to competitive tendering for refurbishment work. Finally, this chapter describes the main risk management strategies and techniques which are applicable to the construction industry.

3.2 Definition of risk and uncertainty

The construction industry is renowned for being a high risk industry. This is clearly reflected in the relatively high proportion of construction firms which went into liquidation in 1988 in comparison with other industries, as reported by the Department of Trade and Industry (1) (illustrated in table 3.1). Risk has been a major problem confronting the industry. Cost and time overruns are commonly encountered by contractors in projects due to unforeseen circumstances. As a result, in recent years many contractors are becoming increasing aware of the problem of risk and realise that their survival depends very much on how they manage these risks effectively and efficiently.

As pointed out by Orsaah (2), the term "risk" possesses a variety of meanings and means different things to different people in different situations. Opinion varies among researchers regarding the precise definition of risk. This is mainly attributed to the different context or discipline in which the concept of risk is being applied. A general definition of risk as suggested by the Association of Insurance and Risk Managers in Industry and Commerce (3) is as follows:-

"Risk has been defined as any situation arising out of an organisation's activities which can give rise to loss, injury, damage, liability or impairment of growth in social, moral and financial terms."

Table 3.1 : Bankruptcies and Company Liquidations: Analysis by industry 1988

(Source: Insolvency : General annual report for the year 1988, Department of Trade and Industry, 1989)

Industry Classification	England and Wales				Scotland		
		Company liquidations			Company liquidations		
	Bank-ruptcies and deeds of arrange-ment	Total	Com-pulsory Liqui-dations	Credi-tors Volun-tary liqui-dations	Total	Com-pulsory Liqui-dations	Credi-tors Volun-tary liqui-dations
Agriculture and horticulture	162	73	31	42	5	3	2
Manufacturing							
Food, drink and tobacco	25	88	14	74	1	1	0
Chemicals	3	75	9	66	5	2	3
Metals and engineering	158	708	226	482	58	31	27
Textiles and clothing	73	811	92	719	9	6	3
Timber, furniture etc	94	242	47	195	8	3	5
Paper, printing and publishing	60	326	109	217	5	2	3
Other manufacturing	30	480	96	384	6	5	1
Construction	1,590	1,471	868	603	67	47	20
Transport and communication	527	548	277	271	11	4	7
Wholesaling							
Food, drink and tobacco	53	125	46	79	7	4	3
Motor vehicles	6	91	11	80	0	0	0
Other wholesaling	69	487	198	289	5	5	0
Retailing							
Food	447	170	78	92	18	13	5
Motor vehicles (including filling stations)	163	121	58	63	10	4	6
Other retailing	459	795	339	456	50	22	28
Financial institutions	86	159	34	125	4	2	2
Business services	325	843	519	324	46	23	23
Hotels and catering	625	359	210	149	15	8	7
All other industries and businesses	646	1,455	405	1,050	66	43	23
Employees	686	—	—	—	—	—	—
No occupation and unemployed	652	—	—	—	—	—	—
Directors and promotors of companies	345	—	—	—	—	—	—
Occupation unknown	444	—	—	—	—	—	—
Total	7,728	9,427	3,667	5,760	396	228	168

Pollatsek and Tversky (4) found that in the fields of economics and business, risk is often defined *"in terms of the distribution of returns or in terms of the properties of the utility function"*. According to Pollatsek and Tversky, although the definition of risk differs among researchers, there are three basic assumptions which are made:-

a) risk is a property of options that affect choice among them;

b) options can be meaningfully ordered with respect to their level of risk; and

c) the risk of an option is related in some way to the dispersion or the variance of the outcomes.

Another definition as put forward by Cooley (5) is that risk *"is associated with uncertainty about future events, and more risk implies more uncertainty."*

In the construction context, Chapman and Cooper (6) defines risk as *"exposure to the possibility of economic or financial loss or gain, physical damage or injury or delay, as a consequence of the uncertainty associated with pursuing a course of action."*

In this study, we are mainly concerned with the financial risks faced by contractors in competitive tendering. Thus, risk may be defined as *"exposure to the possibility of financial loss or gain as a consequence of the uncertainty associated with pursuing a course of action (submission of a tender)."*

3.3 Distinction between risk and uncertainty

Many researchers have attempted to distinguish between risk and uncertainty. Van Horne (7) acknowledged that risk is distinct from uncertainty and argued that *"the distinction between risk and uncertainty is that risk involves situations in which the probabilities of a particular event occurring are known; whereas with uncertainty, these probabilities are not known."* This view is also shared by other researchers such as Sharpe (8), Knight (9) and Duncan (10).

Fellows and Langford (11) in their investigation on decision theory and tendering in the construction industry also distinguish between risk and uncertainty. According to them, risk may be defined *"as an unknown, the probability of occurrence of which can be assessed by statistical means. Uncertainty, on the other hand, is an unknown, the probability of the occurrence of which cannot be assessed."*

However, there are some researchers who argued that risk and uncertainty are synonymous. For instance, Green (12) made no distinction between risk and uncertainty and defined risk as *"the uncertainty surrounding the occurrence of an event which may cause a loss."* Nicosia (13) also acknowledged that *"handling of risk means handling of uncertainty."* Other researchers who adopt similar opinions include Cooley (5), Hertz (14), Bauer (15) and Taylor (16).

Although there is much debate concerning the distinction between risk and uncertainty, in practice such a distinction does not provide much importance to the decision makers. As remarked by Perry and Haynes (17), the distinction between risk and uncertainty is unnecessary and may even be unhelpful in construction risk management.

This view on the synonymity of risk and uncertainty is also shared by Hill and Hillier (18) who acknowledged that:-

"In a business environment, decisions are usually made under conditions of uncertainty rather than risk because it is difficult to anticipate future market and environmental developments and to relate them to events in the past in an objective manner."

Thus, accepting the fact that the construction industry is a highly turbulent and unpredictable industry where it is often difficult to foresee any future changes, many business decisions are made by contractors on the basis of subjective judgements (subjective probability estimates). Therefore, it is appropriate to treat risk and uncertainty as synonymous when considering risk management applications in the industry.

3.4 Sources of risk in competitive bidding

The review of existing literature on risk in the construction industry shows that many researchers hold different opinions with respect to the categorisation of risks in the construction process. A brief outline of various categorisation schemes which have been developed by various researchers follows:-

3.4.1 S.L. Shaffer

Shaffer (19) investigated the application of risk analysis for cost estimating and provided a classification of risk elements as follows:-

a) Design elements.
  - Engineering changes.
  - Field changes.

b) Contingency elements.
  - Labour.
  - Other job conditions.
  - Pricing.

3.4.2 Otto Mendel

Otto Mendel (20) analysed the risks commonly encountered by contractors during their operations. He divided the list of risk factors into two major categories as follows:-

a) Manageable risks.
  - Internal organisation.
  - Undercapitalisation.
  - Competence of personnel.
  - Delegation of authority.

- Contractual arrangements.
- Contract administration.
- Documentation of proceedings.
- Lines of communications.
- Cost control system.
- Labour relations.
- Sub-contract management.

b) Risks outside of contractor's control.

- Labour problems and availability.
- Results of inflationary pressures.
- In-house problems of suppliers or sub-contractors.
- Materials and equipment availability.
- Transportation difficulties.
- Acts of God or Government.

3.4.3 Langford and Wong

In a study involving the assessment of risks in competitive tendering for construction work, Langford and Wong (21) identified a list of major risk factors faced by contractors. These risks may be classified into six categories as follows:-

a) Risks in errors in estimating.

b) Risks due to bad weather.

c) Risks of delay caused by the client, architect, sub-contractors or suppliers.

d) Risks of client's financial failure.

e) Risks associated with cash flow problems.

f) Risks associated with industrial actions.

3.4.4 John Mckirdy

John Mckirdy's (22) analysis of risks in contracting also identifies four main categories of risks in the construction process as follows:-

a) Portfolio risks.
b) Project risks.
c) Catastrophic risks.
d) Risks due to bias in the building system.

3.4.5 J.C. Pim

Pim (23) acknowledged that tender bids vary as a result of bidding "errors" which are classified as follows:-

a) Errors in calculation.
b) Errors in quantity in:-
   - Bill items
   - Rates and standards
   - Magnitude of overheads
c) Errors in judgement in:-
   - Planning and method
   - Assessing learning factor
   - Estimating non-productive costs
   - Evaluating economic environment
   - Guessing number of competitors
   - Guessing attitude of competitors
   - Assessing penalty of failure (or success)
d) Errors in policy in:-
   - Method of application of overheads

- Choice of market

To date, perhaps the most comprehensive study of risk analysis in the construction industry was performed by Perry and Haynes (17). They investigated the risks involved in a construction project at different stages of the project's life and compiled a detailed list of risk factors in construction projects as shown in table 3.2. These risk factors may be grouped into seven main categories as follows:-

a) Physical.
b) Construction.
c) Design.
d) Political.
e) Financial.
f) Legal.
g) Environmental.

Thus, the above discussion shows how opinions differ among researchers in the categorisation of risks in the construction industry. In this study, only the major sources of risks in estimating and tendering of refurbishment work are considered. As described in chapter two, refurbishment work is inherently uncertain in nature and these characteristics pose additional problems to contractors in competitive tendering.

Table 3.2 : Detailed list of risk factors in construction projects

(Source: Perry J.G. and Haynes R.W., "Risk and its management in construction projects", Proc. Instn. Civil Engrs., Part 1, June 1985, 78, pp 499-521.)

	1	2	3	4	5	6	7
Physical							
Force Majeure (Acts of God) – earthquake, flood, fire, landslip, etc	x	x					x
Pestilence							x
Disease							x
Construction							
Delay in possession of site		x					x
Productivity of equipment – possible failure				x			
Availability of equipment, spares, fuel	x						
Inappropriate equipment			x	x			
Weather	x						x
Quality, availability and productivity of labour – manual and management	x	x					
Capability of professional staff							
– competence			x	x	x	x	
– unreasonableness			x	x	x	x	
– partiality			x	x	x	x	
Industrial relations	x			x			
Labour – sickness, absenteeism							
Suitability, availability and supply of materials	x	x	x				
Supply of manufactured items		x					
Quality, availability and productivity of sub-contractors		x	x	x			
New technology or methods – application and feasibility	x	x					
Safety – accidents				x			
Extent of change	x				x		
Failure to construct to programme and specification				x			
Poor workmanship				x			
Ground conditions							
– inadequate site investigation	x				x		
– inadequate information in documents		x	x				
– unforseen problems		x					
Mistakes				x	x		
Relationship of professional staff to each other – consultants architects quantity surveyors, contractors					x		
Co-ordination of all construction contractors	x			x			
Liaison with public services				x	x		
Irregularity of work load			x				
Wastage				x			
Theft		x					
Errors or omissions in bills of quantities			x		x		
Insufficient time to prepare bid tenders	x						
Communication				x	x	x	
Delay in information from designers					x		
Poor design and shop drawings		x			x		
Access							
Damage during transportation or storage				x			
Damage during construction due to							
– negligence of any party		x					
– vandalism		x					
– accident		x					
Design							
Incomplete design scope	x						
Availability of information	x				x	x	
Innovative application	x						
New technology	x				x		
Level of detail required and accuracy		x					
Appropriateness of specification			x		x		
Likelihood of change	x						
Interaction of design with method of construction	x			x	x		
Design—Cont.							
Non standardisation of details					x		
Non standardisation of suppliers		x			x	x	
Quality control exercised – inspection and approvals		x		x	x		
Temporary design – quality, responsibility and supervision		x		x	x		
Political							
Changes in law							x
War, revolution, civil disorder							x
Constraints on the availability of labour	x						
Customs and export restrictions and procedures		x					
Requirement to use local labour or management	x	x					
Requirement to joint venture with local organisations	x	x	x				
Inconsistency of regulations within country or organisation		x					x
Requirement for permits and the procedures for their approval: for building codes and planning permits		x			x		x
Embargo							x
Financial							
Availability of funds of client						x	
Cash flow of client – particularly effect of delay	x	x				x	
Loss due to default of contractor, sub-contractor supplier, client		x		x			
Cash flow problems for contractors due to							
– slow payment by clients of certified work or claims		x			x	x	
– dispute		x		x			
Adequate payment for variations		x			x		
Failure of low bidder to enter construction contract			x	x			
Inflation	x	x					
Exchange rate fluctuation	x	x					
Availability and fluctuation of foreign exchange		x	x				
Repatriation of funds		x					
Local and national taxes		x					
Credit worthiness of contractor			x	x			
Cost of legal decision							x
Insufficient insurance			x				
Business disruption		x					x
Bid validity period extension	x				x	x	
Bid and construction bonds unfairly called						x	
Legal – contractual							
Direct liability		x					
Liability to others		x					
Local law and codes		x					x
Legal differences between countries of client contractors, consultants, suppliers		x					
Conditions of contract, for example							
– liquidated damages, maintenance		x					
– change to 'excepted risks'		x				x	
Environmental							
Ecological damage							x
Pollution		x					x
Waste treatment	x	x	x				
Public enquiry							x
Regulations and possible changes							x
Recording and preserving historical finds	x	x					x
Minority interests							x

Key

1 This risk may have a major influence on the type of contract used, for example the use of target-cost 16 or management type 17 contracts
2 This requires careful assessment in the conditions of contract
3 This has implications for bid procedure and assessment

Management decision on the level of risk may be influenced by the previous experience, by the other parties, of
4 the contractors
5 the designers consultants
6 the client
7 This risk is usually retained by the client

From the literature review and discussion with refurbishment contractors, the major risks commonly encountered by contractors when tendering for refurbishment work are listed in table 3.3 and may be broadly classified as follows:-

a) **Contract related risks:-** This refers to risks which arise as a result of the contractual arrangements between the client and contractor.

b) **Information related risks:-** This relates to risks caused by "information gap" in the tendering process both inside and outside a contractor's organisation.

c) **Protection related risks:-** These risks are mainly concerned with the uncertainty which is inherent in the provision of protective measures required for the proposed refurbishment work.

d) **Personnel related risks:-** This category of risks relates to the nature of the relationship between the client, consultants and contractor.

e) **Work content related risks:-** These are risk factors which are inherent in the work content of the proposed contract such as the intensity of work, the proportion of sub-contractor's work or the size of job.

f) **Work nature related risks:-** These are risk factors attributed to the unique characteristics of the proposed work and include the complexity of the job, site restrictions or degree of structural work.

Table 3.3 : Risk factors in competitive tendering for refurbishment work

CATEGORY	CONSTRUCTS
1) Contract related constructs	a) Contract form b) Liquidated damages c) Contract period d) Restrictions on working hours e) Quality requirements f) Collateral warranty g) Specification of work hours h) Percentage of retention
2) Information related constructs	a) Documentation (Bills of quantities) b) Design information c) Cost estimate d) Number of bidders e) Risk f) Identify of bidders
3) Protection related constructs	a) Noise and dust protection b) Public protection c) Protection of listed buildings and expensive items d) Security e) Protection new of work f) Protection of existing building
4) Personnel related constructs	a) Consultant relationship b) Competence of consultants c) Commercial client d) Familiar client e) Client relationship f) Client credit
5) Work content related constructs	a) Intensity of work b) Phase work c) Timely start of project d) Buildability e) Complexity of contractor's own work f) Proportion of contractor's own work g) Proportion of new work h) Complexity of sub-contract work i) Proportion of specialist work j) Size of job k) Work load of contractor l) Familiarity of work
6) Work nature related constructs	a) Occupation of building b) Degree of temporary work c) Degree of structural work d) Degree of demolition work e) Occupation of domestic building f) Degree of ground work g) Internal or External refurbishment h) Complexity of job i) Restriction of access

3.5 Risk management strategies

Perry and Haynes (17) have suggested a simple and systematic approach to risk management in the construction industry. This approach consists of three distinct stages namely: (i) risk identification; (ii) risk analysis, and (ii) risk response. The first stage involves the identification of major sources of risks pertaining to the decision problem. In the second stage, the effects of these risks are assessed and evaluated. Thereafter, appropriate risk policies and responses are developed to reduce and control the risks involved. Thus, it can be seen from the mechanism of the above process that risk management does not actually remove all risks from a project. It merely provides an organised framework for assisting decision makers to manage risks more effectively and efficiently. The following describes the main activities involved in the risk management process of competitive bidding in the construction industry.

3.5.1 Risk identification

In a bidding situation, the risk management process begins with the initial identification of the relevant and pertinent risks associated with the proposed contract. The contractor must be able to identify both the risks allocated to him through the contractual arrangement (type of contract and contract form) and also the risks which are inherent in the nature of the project. This process entails a thorough understanding of both the contractual and construction procedures involved in the project. Very often, contractors rely upon their experience and intuition to identify and assess such risks. However, this task may be very complicated when dealing with complex projects. The major sources of risk in competitive tendering for refurbishment work have been discussed earlier.

3.5.2 Risk analysis

Once the major risk factors are identified, various measures must be taken to quantify them so that it is possible to determine their effects on the outcome states of the decision.

Various decision criteria (for example, profitability) must be developed so as to facilitate the selection of alternative courses of action by the decision maker. Various risk analysis techniques such as decision tree, probability and simulation, sensitivity analysis and utility theory may be utilised to analyse the effects of these risk factors on the outcomes. Very often, these techniques involve assigning a range of values for each risk factor together with its associated probability of occurrence and analysing the impact on the decision outcome in terms of monetary or utility values. Sometimes, subjective judgement is required to quantify some of the risk factors. This is partly due to the fact that many contractors find it difficult to obtain adequate data to determine the probability distribution of these risk factors. Hence, risk analysis suffers severe limitations (as contractors are sceptical of its reliability and accuracy) especially when subjective judgement is required.

3.5.3 Risk response

Risk may be treated in a number of different ways. There are four common methods in which decision makers can respond to risk which are described as follows:-

a) **Risk avoidance** - As its name implies, this simply involves taking actions to avoid the risk in the decision problem. In competitive tendering, this response may be taken by a contractor when he finds that his risk exposure for the proposed contract is too high or beyond his risk absorption capacity. Risk avoidance may be adopted by a contractor after he has received an invitation to tender. If he is of the opinion that the project involves high risk, he may reject the invitation and return the tender documents to the client thus avoiding any risk in tendering. However, in some cases a contractor may only decide not to submit a bid after detailed appreciation of the project or after the preparation of a cost estimate. Under such circumstances, the contractor may either return the tender documents as before (this is not commonly practiced as it may offend the client) or the contractor may resort to submiting a non-serious bid (cover bid) which is considerably higher, thus deliberately reducing his chance of being awarded the contract. The use of cover bids is one means whereby a contractor can avoid the risks of tendering and at the same time avoid offending his prospective clients. However, caution must be exercised in the submission of cover bids as sometimes a cover bid may turn out to be the lowest bid.

b) **Risk reduction** - Risk reduction strategy is one of the strategies most commonly practiced by contractors in the industry. A common approach is through the use of an information search whereby information is obtained from a variety of sources so as to enable contractors to appreciate and price the contract more accurately. The use of an information search has been recognised by researchers such as Hakannson and Wootz (24), and Covello (25) as one of the most effective strategies for the management of perceived risk. There are two main types of information required by contractors in competitive bidding:-

i) Information which will help the contractor to price his cost estimate accurately (micro level).

ii) Information which will enhance the understanding of contractors with respect to the competitive environment (macro level).

There are a number of information sources which are commonly utilised by contractors for the preparation of cost estimates. This includes tender documentation, enquiries from clients and consultants, site visits, published cost data and historical cost records of contractors. The influence of information on the estimating accuracy has been investigated by various researchers such as Whittaker (26), Bennett and Barnes (27), and Flanagan and Norman (28). Whittaker acknowledged that "estimating uncertainty" is mainly attributed to an "information gap". Bennett and Barnes found that by varying the amount of information available to estimators, the shape of the distribution of the population of cost estimates became flatter indicating higher variability in the cost estimates. Similarly, Flanagan and Norman managed to establish that a negative correlation exists between tender bid variability and the quality of information (as measured by the proportion of prime cost and provisional sum in a tender).

On the other hand, information on the competitive environment is often difficult to obtain due to the sensitivity of such information and the unwillingness of contractors to share tender bid information. Despite these barriers, in practice contractors are able to obtain indicative information concerning the bidding environment through sources such as grape-vine information, contacts with clients, consultants or competitors, sub-contractors, suppliers or through independent organisations such as the Builders' Conference.

Although there is an abundant amount of information available, this information has often not been put to effective use in helping contractors to manage tendering risks. This is mainly attributed to the severe time constraint which is commonly imposed by clients on contractors in the preparation of a tender (two to three weeks). Furthermore, the vast amount of information available both inside and outside a contractor's organisation has not been organised in any comprehensible form. This observation was also made by Cussack (29) who commented that there is an abundance of information but not in the 'right form' to support the decision making process of contractors. As a result, many contractors encounter difficulty in adopting an information search as a risk reduction strategy. Consequently, decisions are frequently based upon intuitive judgement and experience.

Another risk reduction strategy which is commonly practiced by contractors is tender qualification. Contractors may qualify their tender bid or alter certain conditions of the contract, thus reducing their liabilities. This strategy is normally adopted when the contractor finds the contract conditions ambiguous or unfair. But, this practice is normally not favoured by clients and consultants. However, the rationale for taking such action is explained by one contractor (30) as follows:

"One must realise that clients can write any conditions into the documents that they desire. There are circumstances where the client's interests conflict radically with the contractor's interests. There are circumstances where conditions have been written into documents which are so grossly unfair that the contractor has either to qualify or to send the documents back. The difficulties in doing the latter have been touched on (if a contractor does not submit the tender documents, he is liable to be crossed off the architect's list for future invitation to selective tendering), therefore there is no alternative but to qualify. If all documents when sent out were masterpieces of fairness and clarity there would be no need to qualify, but this is an Utopian situation which has certainly not been reached."

c) **Risk transfer** - There are two main routes whereby risk may be transferred by a contractor to another party in competitive tendering as follows:-

i) Contractor to insurer.

ii) Contractor to sub-contractors.

The transfer of risk to an insurer is usually carried out by means of the contractor taking up insurance policies. For instance, the contractor's all risks policy (CAR policy) provides an useful instrument which indemnifies the contractor against *"loss or damage from whatsoever cause to contract works or materials whilst on contract site(s) and in use in connection with the contract specified or type of work described in the schedule and where such loss or damage arises out of performance of the contract and/or during the period of maintenance"*. Similarly, a contractor can also transfer risk of legal liabilities through the employer's liability and the public liability policies. The employer's policy covers the *"liability of the contractor to his employees (those persons under a contract of service or apprenticeship with the employer) for bodily injury or disease arising out of and in the course of employment"*. While the public liability policy indemnifies a contractor against *"personal injury claims by the public and property damage* *claims*". Thus, the adoption of insurance provides an effective way to transfer risks in a contract.

Another means by which main contractors may transfer risks is through the sub-contracting of certain portions of the proposed work to sub-contractors or specialists. This is commonly practiced, especially in refurbishment work which often contains a high proportion of complex and specialised work. But, contractors must be cautious and selective to ensure that such risks are transferred properly to the appropriate sub-contractors (in terms of their competence and risk absorbing capacities). Otherwise, if the amount of risk being transferred is beyond the capacity of the sub-contractor, the risks may be transferred back to the main contractor if the sub-contractor goes into liquidation or when the sub-contractor is unable to complete the sub-contracted work, thus causing much disruption to the overall progress of the construction work. Therefore, most contractors usually maintain a group of sub-contractors with whom they have established a good working relationship or adopt a stringent vetting system in the selection of domestic sub-contractors and suppliers.

d) **Risk retention** - Whatever risk is remaining after adopting the above three risk management strategies has to be borne by the contractor. As suggested by Perry and Haynes (17), these risks may be grouped into two main categories: (i) controllable risks and (ii) uncontrollable risks. Controllable risks are usually managed by either reducing their likelihood of occurrence or reducing their impact if they occur. In competitive bidding, contractors normally allow a contingency sum to cater for any unforeseen circumstances so as to reduce the impact of such risks on the profitability of the project. Contingency allowance is usually provided in the tender bid either as a percentage of the cost of work or as a lump sum. In certain cases, the quantum of risk exposure may be small relative to the risk absorbing capacity of the contractor, especially for large sized firms. Under such circumstances, contractors may instead utilise risk retention strategy as a bidding strategy by not providing any risk allowance, thus increasing their chance of winning the contract.

3.6 Risk management tools and techniques

Over the years, numerous risk analysis techniques have been developed to facilitate the decision making and risk management processes of managers. However, many of these techniques have received limited application in the construction industry. This is mainly due to the sophisticated and theoretical nature of these methods. The following provides a brief review of some of the more common risk analysis techniques which are relevant to the construction industry.

3.6.1 Sensitivity analysis

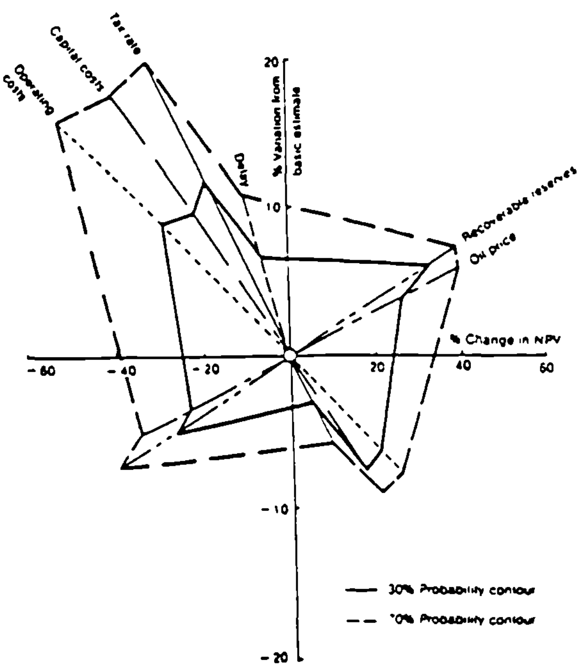
Sensitivity analysis is normally used to study the impact of change in a single risky element or uncertain parameter on the outcome of a decision problem. This technique is frequently used in financial and investment analysis where uncertain factors such as interest rate may be varied so as to determine their impact on the financial returns of investment decisions. The main purpose of sensitivity analysis is to determine the influence of each uncertain element on the outcome and thus identify the major risk factors. Very often, this analysis is performed by assigning a likely range of variation for each uncertain element. The effect of change of the uncertain element on the final outcome is then assessed by varying the value of the uncertain element (within the prescribed range). This process may be reiterated by varying the values of other uncertain elements. When the analysis involves a single uncertain variable, the results may be presented in a simple table to enable a decision maker to choose among the alternatives. But, when there are several variables involved, the results of the analysis may be displayed in a spider diagram (an example is shown in figure 3.1) which provides a clear representation identifying the critical variables (risk factors). The main advantage of sensitivity analysis is that it enables a decision maker to identify critical risk factors so that appropriate actions may be taken to reduce the risks involved. However, this technique has certain limitations:-

i) the variables are treated individually and this leads to severe limitations in the extent to which combinations of variables can be assessed directly from the data.

ii) it provides no indication of the anticipated probability of occurrence of any event.

Figure 3.1 : An example of a spider diagram for sensitivity analysis

(Source: Perry and Haynes, Proc. Instn. Civ. Engrs., Part 1, 78, June 1978)



3.6.2 Probability analysis

The use of probability theory provides a powerful and sophisticated form of risk analysis. Probability analysis overcomes the limitations of sensitivity analysis by specifying a probability distribution for each uncertain variable and thus provides the mechanism which allows all variables to change their values at the same time. However, in practice it is often difficult to quantify all risk factors, particularly in the construction industry where projects are unique in nature and their operating environment highly dynamic. Thus, inadequate data prevents the quantitative derivation of the probability distribution of many uncertain elements. As such, subjective judgements are often required to estimate the probability of occurrence of uncertain events. Sometimes, this problem of specifying probability distribution is overcome by utilising a sampling approach such as the Monte Carlo simulation technique. Therefore, although probability risk analysis provides a more quantitative approach to risk management, it is not commonly used by contractors. This is partly due to its complex nature and the scepticism which contractors possess regarding the use of subjective judgement to estimate the probability distributions of various uncertain elements.

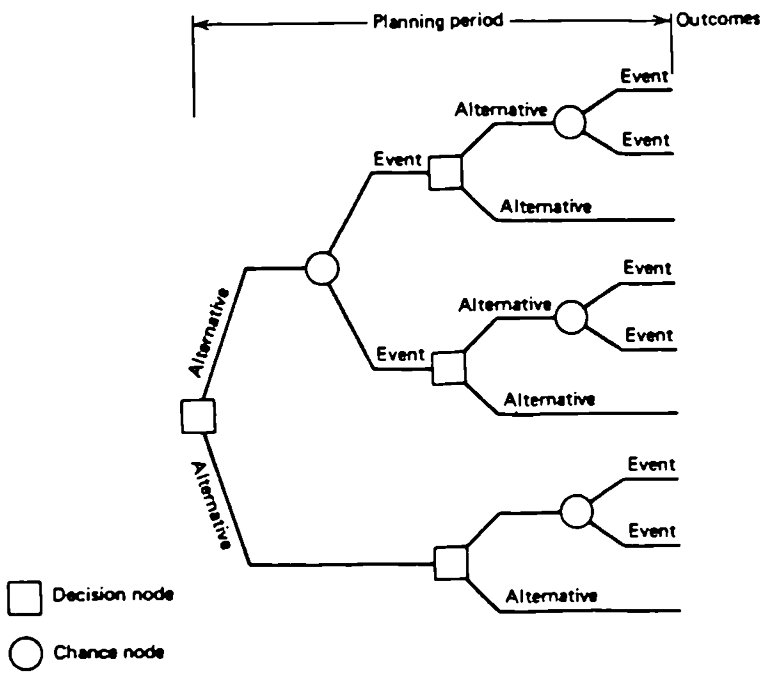
3.6.3 Decision tree analysis

In this analysis, the anatomy of a decision is displayed diagrammatically using a decision tree as shown in figure 3.2. The decision tree clearly shows the possible courses of action together with the outcomes and associated probabilities of various outcome states. As illustrated in figure 3.2, the branches of the tree represent either decision alternatives or chance events. Decision alternatives originate from decision nodes as indicated by the squares while chance events emanate from chance nodes (represented by circles). The decision tree branches from the left to the right displaying various decision points and chance events of the decision problem over a specified time period (planning period).

Thus, the structuring of a decision problem in this manner facilitates the decision making process of managers. This technique has an obvious advantage as it forces the decision maker to assign probabilities to various outcomes and to quantify these outcomes, thus allowing the decision maker to evaluate the decision alternatives. Various researchers such as Chapman and Cooper (6), Ashley (31) and Shaifer (32) have applied this technique in the construction industry.

Figure 3.2 : A decision tree

(Source: L. Shaifer, Construction Management and Engineering, John Wiley & Sons, 1982)



3.6.4 Utility theory

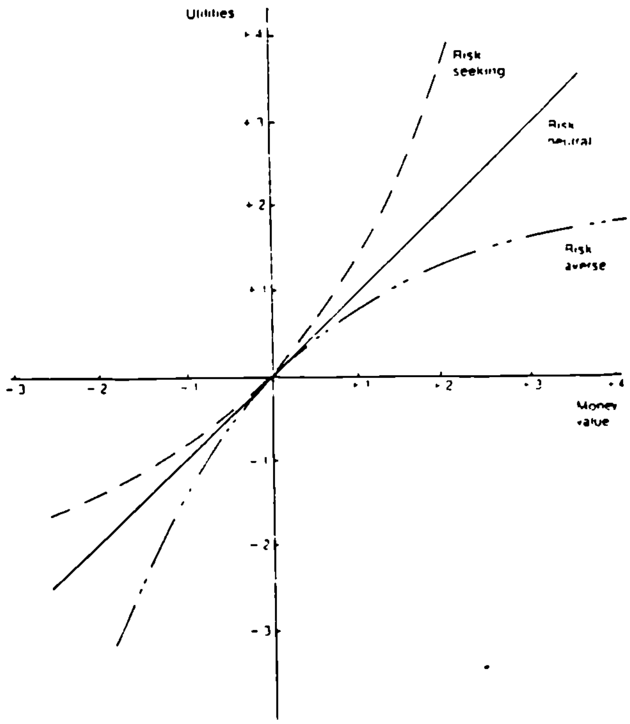
Utility theory basically originates from the work of Von Neuman and Morgenstern (33). It is a psychological concept which is used to measure the desire of individuals to possess units of a given commodity. It provides the basic foundation for modelling the value system of an individual decision maker. In the past, most work on risk analysis focussed on the use of Maximum Expected Value (MEV) criteria (usually expressed in monetary units) as a basis to assist decision makers evaluate and choose among decision alternatives. However, this approach has been criticised for failing to appreciate the non-linearity of the value system of individuals. As acknowledged by Von Neuman and Morgenstern:-

i) There exists an interval scale for measuring the preferences (utility scale) of individual decision maker.

ii) This utility scale is defined in such a manner that if the decision maker chooses the alternative with the highest expected utility, his *"choice will be consistent with the expressed preferences that were used in defining the scale."*

Using a method called Standard Gamble technique, Von Neuman and Morgenstern developed a procedure for determining the utility function of individuals. As shown in figure 3.3, there are three common characteristic forms of utility functions (curves): (i) risk averse, (ii) risk neutral, and (iii) risk seeking.

Figure 3.3 : Utility functions of individuals



Once the utility function of the decision maker is determined, it is then possible to transform expected monetary values into expected utilities by multiplying the utility value of each outcome and its associated probability. In cases where there are several possible outcomes, the expected utility value for each alternative course of action is determined by summing the weighted expected utility values of all possible outcomes for that course of action. This is expressed as follows:-

$$EUV_A = P_1\ u(O_1) + P_2\ u(O_2) + \ldots\ldots\ldots\ldots\ldots\ldots P_n\ u(O_n)$$

where $u(O_1) + u(O_2) + \ldots\ldots\ldots\ldots\ldots\ldots u(O_n)$ are utility values as a consequence of action A and P_1, P_2, $\ldots\ldots\ldots P_n$ are the associated probabilities of each outcome respectively.

Once the expected utility value of each decision alternative is determined, the decision maker will then be able to select the course of action which yields the Maximum Expected Utility (MEU). Thus, the Utility theory approach provides a better representation of the value system of the decision maker. Furthermore, it also measures the risk attitude of the decision maker. In spite of this, Utility theory is seldom applied in the construction industry. This is because contractors tend to regard this approach as theoretical. Furthermore, it is often difficult to accurately determine the utility functions of decision makers.

3.7 Normative process of decision making

The process of decision making usually involves the selection of an act or course of action from among alternative acts or courses of action. Generally, a rational decision maker is one who would desire to select the course of action or act that will produce the optimum results under certain criteria of optimisation. This section attempts to explain some of the basic concepts of decision making and their potential applications in the construction industry.

3.7.1 Definition of decision making

Various writers have defined decision making in a variety of ways. The essential ingredients of a decision making process may be summarised in a simple definition as follows:-

"Decision making simply consists of a choice between two or more options after an evaluation of these options and in the light of progress towards fulfilling an objective or objectives."

3.7.2 Decision making process

There is a vast amount of literature on the study of decision making processes. But, perhaps one of most distinguished and respected writers is Herbert A. Simon (34). According to Simon, the central issue of any decision making process is that of rational behaviour. As illustrated by Simon, a decision making process basically consists of three distinct stages as follows:-

a) **Intelligence stage** - This involves the surveying of the economic, technical, political and social environment in order to identify conditions or circumstances calling for new actions. It is basically finding occasions for making a decision.

b) **Design stage** - In this stage, the decision makers invent, develop and analyse possible courses of action. Thus, this stage consists of finding all possible courses of action to a decision problem.

c) **Choice stage** - This simply consists of choosing one of the alternative courses of action.

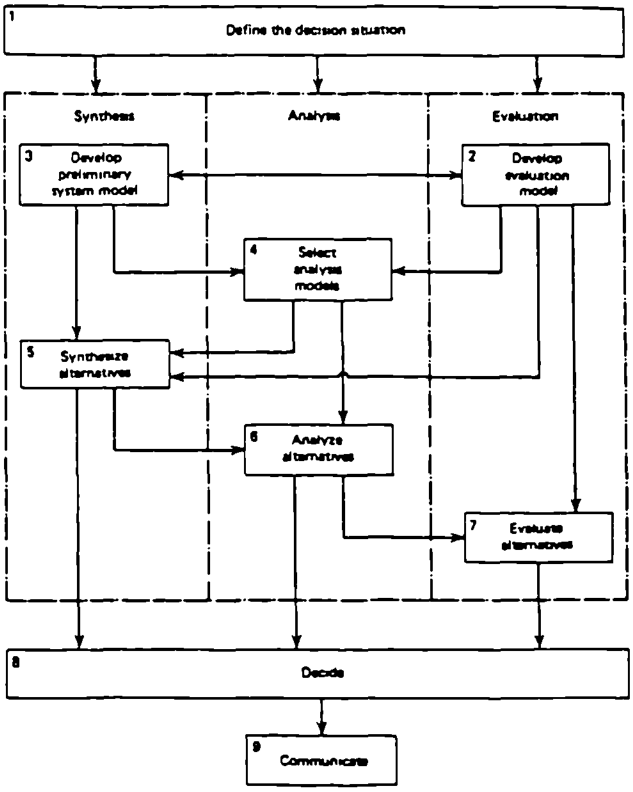
3.7.3 Decision making model

Numerous attempts have been made to develop decision making models to facilitate the decision making process of management in various industries. Most of these models attempt to provide a "systematic framework" for structuring the decision-making process so that quantitative analysis or evaluation models may be utilised to enable management to select the optimum course of action under various circumstances. A typical decision making model as proposed by Shaifer (32) is illustrated in figure 3.4.

Figure 3.4 : A typical decision making model

(Source: L. Shaifer, Construction Management and Engineering,

John Wiley & Sons, 1982)



The main objective of this model is to present a sequence of activities aimed at providing guidance to management in order to perform the synthesis, analysis and evaluation of data for the purpose of generating the necessary information on which the decision is based. Thus, this model provides an effective management tool facilitating the decision making process of managers.

3.7.4 Elements of a decision

There are five main elements of a decision which are described briefly as follows:-

a) **Decision maker** - This is the primary element of any decision situation and may comprise of individuals or groups who have been designated the relevant authority to select a course of action in the decision problem. In competitive bidding, decisions with respect to the cost estimating and tender adjudicating processes are often made by estimators and directors of the firms respectively. The decision process may be performed individually or in a group depending on the policy and size of the company. Generally, tender decisions in smaller firms (especially sole proprietorships) are made by individuals while large construction firms tend to adopt group decision making.

b) **Candidate alternatives** - This refers to the alternative courses of action surrounding a decision problem. In a bidding situation, two main decisions are usually made as follows:-

i) Which of the jobs to bid on ?

ii) How much to bid ?

Alternative courses of action for the first decision include whether to bid for job X or job Y or job Z or other jobs. While in the second decision situation, the candidate alternatives consist of submitting different amounts for a tender bid.

c) **States** - Very often, the consequences of a decision depend upon conditions which are external to the decision making process. Although such conditions affect the results of the decision, they are not themselves being influenced by the decision. These external conditions are termed "states of nature". The set of states is often exhaustive (that is, some members within the set must occur) and mutually exclusive (that is, only one state can occur at a time). Examples of states of nature which may affect the results of a tendering decision include weather conditions, inflationary fluctuations or industrial action.

d) **Outcomes and decision criteria** - The consequences estimated for each alternative course of action under each state are termed outcomes. In a bidding situation, there are usually several outcomes arising from a number of consequences of a decision. These outcomes are usually measured by several characteristics or dimensions (economic or physical). In practice, the decision maker normally only considers the most significant dimensions of the outcomes and these are termed his decision criteria.

e) **Value systems** - In selecting an alternative from a set of candidate alternatives, the decision maker uses his "value system" to evaluate the alternatives so as to enable him to select the optimum course of action which best satisfies his goals. There are two common approaches which have been developed to represent the value system of a decision maker namely: (i) Maximum Expected Value criteria and (ii) Maximum Utility Value criteria. In the Maximum Expected Value approach, outcomes of each alternative course of action are usually transformed into monetary units in order to allow decision makers to make meaningful comparisons among alternatives. Similarly, the Maximum Expected Utility Value method adopts an utility scale to represent the value system of decision makers. In this case, outcomes of candidate alternatives are expressed in utility values to facilitate decision making.

CHAPTER FOUR

PERCEPTION OF RISK (PERSONAL CONSTRUCT THEORY)

CHAPTER FOUR

PERCEPTION OF RISK (PERSONAL CONSTRUCT THEORY)

4.1 Introduction

This chapter describes the theoretical background of Personal Construct Theory as developed by Kelly (1). Particular emphasis is placed on the use of Repertory Grid Interview technique as a means to measure people's perception. The logical procedure of the Repertory Grid Interview is also discussed together with various techniques commonly adopted to elicit personal constructs of people.

4.2 Personal Construct Theory

Personal Construct Theory was first established in 1955 by a psychologist named George Kelly (1). According to George Kelly, each person builds for himself a representational model of the world which enables him to plan a course of behaviour. This model changes over time as constructions of reality are tested and modified so as to allow better predictions. As pointed out by Kelly,

".... a person's processes are psychologically channelised by the ways in which he anticipates events"

Throughout a person's life, he questions, explores, revises and replaces constructions in attempts to anticipate events in the light of predictive failure. People make sense of situations by imposing certain structures on them. This proposition is well explained by Kelly as follows :-

"We impose the structure - events do not carry their meaning engraved on their backs."

From birth, we build up a set of expectancies ("hypotheses") which clearly reflect our past experiences. However, the crucial point is that these hypotheses influence and condition our present experience and our anticipation of the future. They are like a pair of spectacles through which we get information but which also affect what we see and how we see it. Kelly called the "spectacles" a construct system, and termed the individual hypotheses *constructs*. There are certain unique properties of constructs which must be understood in order to facilitate communication and shared understanding as described below.

a) The medium through which perception occurs is the construct system.

b) Construct systems are unique to individuals and develop throughout life.

c) A construct is an aspect, feature or quality which distinguishes some objects from others. It is an axis of discrimination to all thinking operations - a reference axis upon which one may project events in an effort to make sense of what is going on. According to Kelly, a construct always involves a basic contrast of similarity and difference.

d) Kelly (1) grouped constructs into three types.

   i) Pre-emptive constructs group objects exclusively in their own realm (for example, species name). This is an X and nothing but an X.

   ii) Propositional constructs are not exclusive and do not prevent objects being construed by other constructs. This is an X, but it can also be a Y.

   iii) Constellatory constructs fix membership not only to one, but on several constructs. If it is an X, then it must also be a Y.

e) Constructs are linked together in a hierarchical manner to form a construct system.

f) The psychological processes of two persons are similar to the degree in which both of them construe certain sets of similar experience.

g) Similarly, to the extent that one person construes the construction processes of another, he or she may play a role in a social process involving the other.

h) The constructs most useful to us are those which discriminate best between events.

i) Constructs have a limited range over which they operate.

4.3 Repertory Grid technique

The Repertory grid technique originates from Kelly's (1) Personal Construct Theory. Originally, this technique had been adopted to investigate the relationships between patients and their families, friends or colleagues and to assess the relationships between a patient's constructs about people. Its procedure is closely linked to the theoretical roots of Kelly's definition of a construct. As put forward by Kelly, a construct is " *in its minimum context, a way in which two elements are similar and contrast with the third.*"
This distinction has been emphasised by Fransella and Bannister (2) who state that :-

"When we say that Bill Boggs is honest, we are not saying that Bill Boggs is honest, he is not a chrysanthemum or a battle-ship or the square root of minus one. We are saying that Bill Boggs is honest, he is not a crook. "

Thus a construct is basically a dimension which may evolve when considering a particular set of elements but can usually be applied to a further range of elements. The dimensionality of a construct allows one to extract matrices of inter-relationships between constructs and between elements.

Kelly also observed that constructs do not exist in isolation but in fact they are closely linked to one another in more or less coherent and hierarchical manner. A person's constructs may be grouped into two categories namely:- "core" constructs and "peripheral" constructs. "Core" constructs are of central importance to the individual and often remain very stable and more resistant to changes. On the contrary, "peripheral" constructs are subject to changes and occur at different levels of an individual's construct system.

Laddering is a technique commonly adopted to move between construct levels. Given a construct, one can either ladder "upwards" towards the central construct by asking which pole of that construct is more important to the individual and why. For example, in investigating the constructs of an individual about efficiency at work and the construct "keeps good time/always late" is elicited. It is possible to obtain further constructs (for instance, construct such as "shows commitment/no commitment" may be elicited by laddering from the "keeps good time/always late" construct) by asking the "why" question. This process may repeated until the central construct of the respondent is revealed. Similarly, constructs could also be laddered "downwards" by using the "how" or "what" questions instead to obtain more specific constructs.

There are some definitions of terms commonly adopted in the Repertory Grid Interview as follows:-

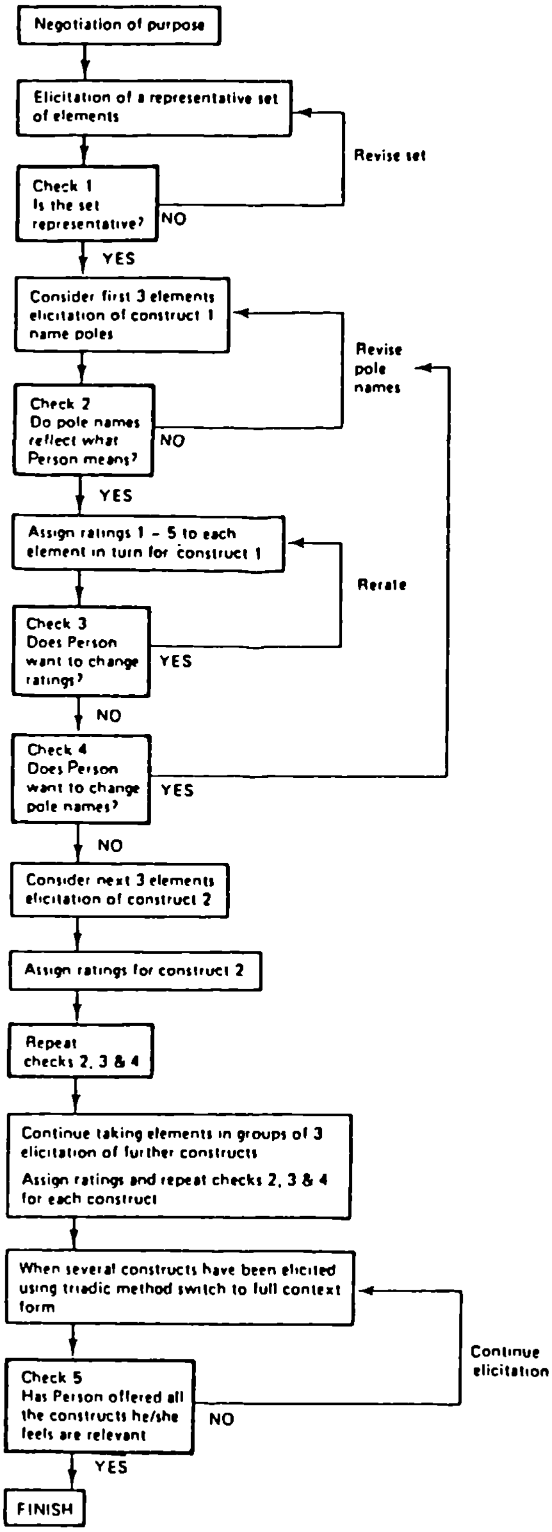
a) **Element** - This is the subject of the investigation and may consist of objects, people, situations or even other abstract descriptions. There are two main points which should be noted in the selection of elements:-
   i) Elements should be homogeneous - They should be chosen from the same category.
   ii) The selected elements should provide representative coverage of the area of investigation.
b) **Constructs** - These are bi-polar distinctions of the elements and represent the dimensions which the respondent uses to discriminate the elements.
c) **Construct elicitation** - This is the process of obtaining constructs from the respondents based upon triadic method, dyadic method, free response method or a combination of these methods.

4.4 Repertory Grid Interview procedure

There are many well established methods used in practice to elicit the construct system of individuals. The most typical approach as illustrated by Pope and Keen (3) is shown in figure 4.1 and involves the following steps.

Figure 4.1 : Flow diagram for grid elicitation

(Source: Pope and Keen, Personal construct psychology and education, 1981, Academic Press)



4.4.1 Defining the purpose of the grid

This is the most important preliminary consideration before beginning the process of eliciting elements and constructs. Two issues must be clearly addressed and answered at this stage.

a) What is the topic to be investigated ?

b) What is the intended use of the grid information ?

It is essential that adequate time and consideration should be given to define the purpose of the investigation. With a clear objective defined, it is then possible to select representative elements and elicit constructs which are appropriate to the purpose of the exploration.

The second issue on the intended use of the grid information has an influence on the format and procedure of grid elicitation. There are various ways in which the grid information could be used. The following list provides some examples of its potential usage:-

a) a conversation with one's self;

b) gathering of information about an individual's views on a particular topic;

c) a comparison of the viewpoints of two people in terms of either:-

    i) degree of agreement between, or

    ii) the degree to which either can gauge the other's point of view;

d) an exploration of the nature and sharing of construing within a group;

e) monitoring of changes in perspectives.

4.4.2 Selection of elements

This involves the selection of a set of elements representative of the area of investigation. Elements may consist of objects, events, situations, pictures, buildings or people. They could be provided by the researcher or elicited personally from the respondents. The choice between elicited and provided elements depends on the researcher and also the purpose of the investigation. However, it is important that adequate groundwork should be done to ensure that the selected elements are representative of the nature of the problem to be investigated. Normally, this would entail discussion or conversation with the potential subjects so that a common understanding could be achieved between the researcher and the subjects.

Thus, in order to determine the risk perception of contractors during tendering, it is necessary to elicit various representative bidding situations which will reflect the experience and risk attitude of the contractors. Generally, there are four distinct ways in generating elements as follows:-

a) **Supply elements (Provided elements)** - The elements are provided by the researcher.
b) **Provide role or situation description** - The researcher provides description on certain role, object or situation and the respondent is requested to provide examples to fit the description.
c) **Defining a "pool"** - The respondent is asked to "name five effective managers" or "list seven types of perfumes she likes" or "to list five leisure activities he or she indulges in".
d) **Elicit through discussion** - The researcher discusses the topic of investigation with the respondent providing guidelines and prompts to elicit the appropriate elements.

In the past, there has been some debate among researchers comparing the usefulness between provided and elicited constructs. For instance, Bonarius (4) in his study suggested that:-

".... subjects consistently use the more extreme poles of rating scales when using personal constructs rather than provided constructs in rating themselves and others."

However, the controversy between provided and elicited elements in Repertory Grid technique was well summarised by Adams-Webber (5) who commented:-

"Although normal subjects prefer to use their own elicited constructs to describe themselves and others, both kinds of dimensions seem to be functionally similar when the grid technique is employed to assess the structural features of their cognitive systems."

Another question commonly asked is "how many elements should a Repertory Grid contain ?". Ideally, it would be very informative to have a large number of elements. But, the task of construing a large number of elements can be very tedious and time-consuming. On the other extreme, a small number of elements may provide insufficient details or a devoid grid. In practice, between 6 to 10 elements would provide a useful basis for the elicitation of a reasonable grid.

4.4.3 Elicitation of constructs

Normally, the elicitation of constructs is carried out by presenting a random set of three elements at a time to the respondent and inviting him or her to think of similarities and differences between the elements. The standard question is:-

"In what ways are two of these alike and different from the third in terms of ....(purpose of study) ?"

As described by Kelly (1), there are six principal approaches to the elicitation of constructs as follows:-

a) **Triadic construct elicitation** - In this method, the respondent is presented with three elements at a time from a list of representative elements and asked to distinguish in what ways are two of the elements are alike and different from the third. The respondent is then requested to name the emergent pole and the implicit or contrast pole which discriminate the elements. The two contrasting poles of the construct are then recorded.

b) **Dyadic construct elicitation** - As suggested by Keen and Bell (6), this method is used when the respondent finds it difficult to supply any constructs. Each time, two elements are presented to the respondent to enable him to discriminate the differences or likeness between them.

c) **Free response construct elicitation** - Through conversation, respondents provide their personal constructs instinctively.

d) **Supply constructs** - This is the fastest way to generate constructs whereby the researcher provides pre-determined constructs for the respondent to assign the necessary ratings.

e) **Laddering** - This technique is normally used in conjunction with one of the above methods after some constructs have been elicited. It involves asking the respondent a series of "Why" or "How" questions so as to elicit more specific constructs.

f) **A combination of the above methods.**

One point which should be emphasised is that the researcher should ensure that the elicited constructs are appropriate to the purpose of the investigation. There are four different types of constructs which may arise from the elicitation process:-

i) **Sensory-perceptual** - These constructs are normally elicited when investigating the perceived attributes of objects or situations. For example, the elicitation of personal constructs of quality controllers who are working on a production line.

ii) **Behavioural/Inferential** - These constructs reflect upon the behaviour of the subjects on certain persons or situations. For example, it would be appropriate to elicit behavioural constructs of shoppers or consumers.

iii) **Feelings/attitudinal** - These constructs describe the feelings or attitude of individuals towards certain persons, objects or situations such as the constructs of workers when working on production line.

There is also the question as to how many constructs should be included in the repertory grid. As suggested by Kelly (1), it is vital to elicit several constructs in order to explore an individual's world of meaning. Thus, it is necessary to achieve a balance between eliciting sufficient numbers of constructs and the practical constraints present. This consideration is well put forward by Maureen L. Pope and Terence R. Keen (3).

"one is not aiming to encapsulate the whole of an individual construct system but only that part of it which is relevant to the defined purpose."

However, there are some criteria and limitations to consider when eliciting constructs:-

a) The constructs elicited must cover the range of constructs which the individual feels are important to the area under consideration. Construct elicitation should continue until the individual indicates that his repertoire of constructs for that particular range of events is exhausted.

b) The elicitation of constructs can be exhausting both for the person completing the grid and the person carrying out the grid interview. Thus, the researcher should be careful not to stretch beyond the limits of exhaustion. Otherwise, the constructs obtained may be unreliable and inaccurate.

c) In many circumstances there may be time limit constraints on behalf of either the individual or the person conducting the grid interview which may well impose a limitation on the number of constructs which are elicited at any one session.

d) It is necessary to consider the limitations of computer software used for the analysis, such as the number of constructs and elements.

4.4.4 Rating of elements of each construct

Kelly's (1) original approach adopted a dichotomous form of grid whereby respondents were asked to place ticks or crosses across elements for each construct. But, this method does not permit finer discrimination between elements or constructs. Furthermore, as noted by Bannister (7), the dichotomous grid may produce spurious relationships possibility caused by lopsidedness (too many ticks and few crosses or vice versa) on a particular construct.

As such, in recent years two popular forms of the grid have emerged namely:- rating (Bannister and Fransella) (2) and ranking (Bannister and Mair) (8) grids. Generally, in practice it is less tedious for the respondents to rate elements than ranking them, especially when there is a large number of elements. Thus, rating of elements is commonly used whereby the respondent is free to assign rating along a linear scale from the emergent pole to the implicit pole of each construct. A 5-point or 7-point scale is usually employed which provides much finer discriminations between elements and constructs.

4.4.5 Analysis of grid

Once the grid is fully completed, the element by construct matrix is then analysed for its underlying structure. There are five principal methods of analysing the full grid data as follows:-

a) **Frequency counts analysis** - This analysis simply counts the number of times a particular construct or element occurs from all the respondents. It is commonly used to identify general trends among groups of people. This analysis is frequently employed when the elements are discrete and well defined and have consistent meanings to the subjects.

b) **Content analysis** - In content analysis, all elements or constructs are grouped into different categories with respect to their similarity in content. A frequency analysis is then performed to determine the distribution of various elements or constructs in these categories. A simple Chi-square test may be conducted to compare the relative distributions of categories across two or more groups of respondents.

c) **Visual focusing** - This technique is normally used on a raw grid with ticks and crosses rather than on a rated grid. In a ticks and crosses grid, it compares the degree of agreement of each construct across the elements and produces a matrix of agreement scores for all possible pairs of elements. Similarly, it is also possible to compare the degree of agreement of various elements over different constructs.

d) **Cluster analysis** - The clustering technique developed by Shaw and Thomas (1976) (9) attempts to group or cluster similar elements or constructs so as to exhibit certain patterns of the original grid data. There are several computer packages such as Pegasus and Focus developed by Shaw and Thomas (9) available for performing cluster analysis. These programs usually produce a linear re-ordering of elements or constructs to highlight similarities in the way in which they are construed. A typical computer printout may consist of the following information:-

   i) The original raw grid.
   ii) A matching score matrix of the relationships between all pairs of elements.
   iii) A matching score matrix of the relationships between all pairs of constructs (with ratings reversed as well as originally rated).
   iv) A statement as to which constructs (if any) should be reversed.
   v) A re-ordered grid with tree diagrams attached showing the patterns of relationships in the data.

e) **Principal Component analysis (Factor analysis)** - This method of grid analysis was developed by Slater (10) in 1964. It is based upon two matrices of similarity measures - an element matrix which includes the measure of similarity of every element with every other element, and the construct matrix which shows the measure of similarity of all pairs of constructs. These measures of similarity are viewed as distances in space or dimensions. This analysis extracts the major dimensions which then describes each of the elements or constructs to these dimensions.

The Principal Component analysis is a statistical technique commonly used to identify a relatively small number of factors that can be used to represent the relationships among sets of many interrelated variables. It is a data reduction technique for identifying a set of independent factors in data. The basic assumption of this technique is that there exist underlying dimensions or factors that can be used to explain the complex relationships of certain variables such as the intelligence, creativity or risk perception of people. Factor analysis is usually performed in four logical steps as follows:-

i) The computation of a correlation matrix of all variables to determine the association among various variables.
ii) The second step involves factor extraction where a number of factors (dimensions) necessary to represent the data is determined.
iii) The third step, rotation, focuses on transforming the factors to make them more interpretable.
iv) Lastly, a score for each factor is computed for each case.

There are also computer programs such as Griddle (Keen and Bell) (6) and Ingrid (Slater) (10) for analysing the intraclass relationships between elements and constructs of the Repertory Grid. The main output of these programs provides the following information (which is described in chapters eight and nine):-

i) Listing of raw grid data.
ii) Table of construct statistics and construct correlation matrix.
iii) Table of element statistics and element correlation matrix.

iv) Table of principal components

v) Graphical output of elements and constructs on major dimensions.

One aspect of computer analysis which is worthwhile mentioning is that the use of computer packages simply reduces the amount of work required to analyse and interpret the full grid data. The computer analysis does not add any new information to the grid and also does not provide indications of the meaning of the grid. It merely summarises the data in a more understandable form. This point is well emphasised by Kelly (1):-

"Neither abstraction nor generalisation has ever been computerised....What can be computerised ...is the elimination of redundancy in a construction matrix. The resultant shrinkage in the matrix is sometimes mistaken for abstraction, or it appears to result in the expression of a great deal in relatively few terms. But the contribution the computer makes is to economy of the language employed, not to conceptualisation....."

4.4.6 Feedback to respondent

When the full grid is completely analysed and certain patterns or relationships between elements and constructs are established, this information can be fed back to the respondents. This feedback may serve as a confirmation process for these relationships or any associations found. Further constructs or elements may also be elicited using laddering to investigate more specific constructs of the respondents.

Thus, this chapter provides an insight into the theoretical background of Personal Construct Theory and the use of Repertory Grid Interview technique as a research instrument for measuring the risk perception of people. The main research strategy when adopting the Repertory Grid Interview to elicit risk perception constructs of contractors (directors and estimators) when they are assessing risks in competitive bidding is discussed in chapter 7.

CHAPTER FIVE

REVIEW OF CURRENT BIDDING MODELS

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REVIEW OF CURRENT BIDDING MODELS

5.1 Introduction

This chapter provides a review of past bidding models which have been developed both in the Construction and Operations Research industries. A background of bidding theories is provided describing the developments of various bidding models since the first competitive bidding model developed by Friedman (1) in 1956. Discussions are made with respect to the different distinctive approaches which various researchers have taken to develop models for assisting contractors to manage risks in competitive bidding. A brief review of the more prominent bidding models is provided highlighting the main benefits and limitations of these models. Besides this, criticisms are made regarding the limited practical applications of many bidding models in the construction industry. Suggestions to improve risk management in competitive bidding are also proposed.

5.2 Background of bidding theory

Competitive bidding is one of the most critical activities of contractors in the construction industry. To date, this form of contract procurement is still a common method adopted by both the public and private sectors for awarding contracts to contractors in the industry. But, bidding is a tricky process which demands considerable judgement on the part of the contractor. Normally, in a bidding situation, a contractor must first estimate the cost of the proposed work (after assessing all the uncertainties involved in pricing the materials, plant and labour), and thereafter add a markup to cover for his overhead, profit and any risk allowance if necessary to form a tender bid. In order to make a profit on the job, he must submit a bid which is lower than his competitors, and at the same time the bid must enable him to make a profit or at least cover his costs. If he bids too high, he may fail to win the contract and thus lose time and money spent on the preparation of the tender. On the other hand, if his bid is too low, he also loses as he may have undertaken the job at a lower price than necessary. This phenomenon is commonly termed as "having left too much money on the table". Thus, if he adds too high a markup to his bid, he may not win enough contracts to stay in business. Conversely, if his markup is too low, he may win many contracts but may not make enough money to stay in business. This dilemma which is commonly faced by contractors in competitive bidding is well expressed by Park (2) as follows:-

"In competitive bidding, the contractor is faced with two seemingly incompatible and contradictory objectives: he must bid high enough to make a profit, yet low enough to get a job - both at the same time!"

The severity and prominence of risk in competitive tendering has motivated the development of numerous bidding models over the years. Most of these models have attempted to provide guidance to bidders in the selection of an *"optimum bid"* under various bidding situations. Much effort has been concentrated in the development of a probabilistic model which will enable a contractor to predict his chance of winning a contract under various competitive situations by producing statement such as *"if you bid at a markup of x%, you will have y% chance of winning a contract"*

However, many of these models have received limited practical applications in the construction industry. This is mainly attributed to the fact that there is an apparent lack of consensus among bidding experts with respect to the basic concepts of bidding theory. Furthermore, the results of all these models are not conclusive and many models have been criticised for being too theoretical in nature, involving mathematical expressions which are too complex.

5.3 Current competitive bidding models

From the literature review of current bidding models, it is observed that although many models have been developed, most of these efforts have adopted a number of distinct approaches to the competitive problem. This may be broadly classified into the following categories:-

a) Expected Monetary Value bidding models;
b) Expected Utility Value bidding models;
c) Other approaches which include cash flow analysis, portfolio theory, game theory, tender bid pattern analysis and simulation methods.

5.3.1 Expected Monetary Value bidding models

This is the principal approach adopted by many researchers such as Friedman (1), Park (2), Gates (3), Casey and Shaffer (4), Whittaker (5), Benjamin (6), Broemser (7), Howard (8), Flanagan and Norman (9), Shaffer and Micheau (10), Oren and Rothkopf (11), Wade and Harris (12), Sugrue (13) and Skitmore (14). Essentially, this method attempts to identify an "optimum markup" which will enable a bidder to maximise his expected profit when submitting a tender bid.

The basic premise underlying this approach is that there exists a relationship between the probability of winning and the tender bid. It is assumed that in a bidding situation, a contractor will normally estimate the cost of work and then add a markup to form the tender bid. If he is desperate for jobs, he will lower his markup so as to achieve a higher chance of winning. On the other hand, if he is not keen on the job, he will increase his markup thus reducing his chance of success. Therefore, between these two extremes there exists a continuum of bids (with various markups) with associated probabilities indicating their chances of successes. Thus, the competitive bidding problem is to formulate this relationship mathematically.

5.3.1.1 Friedman's model

Friedman (1) was the first to attempt to establish this relationship by introducing the concept of expected profit to competitive bidding. He assumed that the main objective of a contractor is to maximise his expected profit, that is, his expected monetary value, in every bidding situation. In deriving the profit function of a bid, he also assumed that the actual cost of fulfilling a contract is a random variable and the ratio of the contractor's true cost (actual cost) to his estimated cost (termed the "s" ratio) is also a random variable. As such, his model may be expressed as follows:-

Profit function:-

$$p = b_0 - s\, c_0$$

where p = profit which will be realised if b_0 is less than all other competitors.

b_0 = bid submitted by contractor.

c_0 = cost estimate of contractor.

The expected profit of a given bid is then determined by multiplying the probability of beating all other competitors with that particular bid and the amount of profit that will be realised if the bid wins. This is determined as follows:-

$$E(p) = \int_0^{\infty} P[(b_0 < b_1) \cap (b_0 < b_2) \cap \ldots \cap (b_0 < b_n)] \times \int (b_0 - s\, c_0)\, h(s)\, ds$$
$$= P[(b_0 < b_1) \cap (b_0 < b_2) \cap \ldots \cap (b_0 < b_n)]\,(b_0 - c')$$

where b_i, i=1,2,3,.........n, are bids of n competitors and h(s) = the density function of the ratio of the true cost to the estimated cost. If μ_s represents the mean of the ratio of the true cost to the estimated cost, then

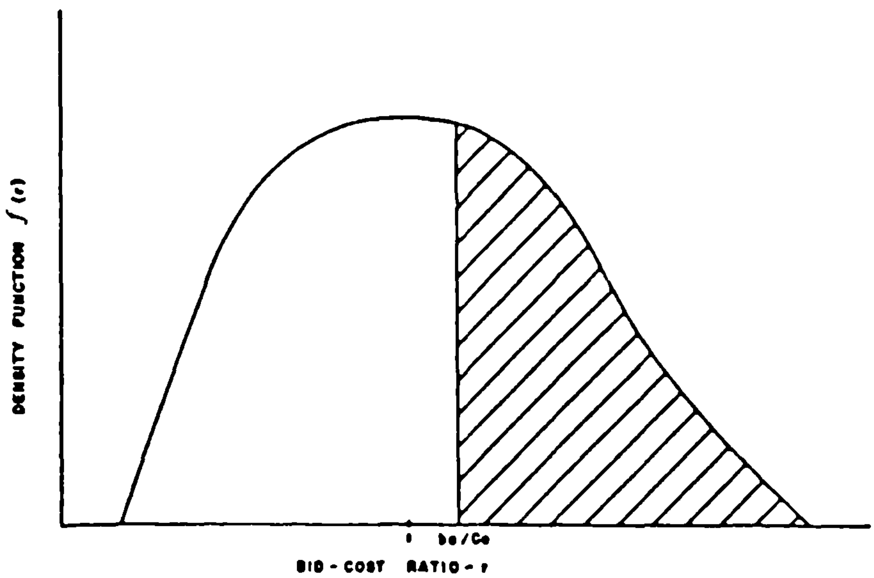
$$c' = c_0 \int_0^{\infty} s\, h(s)\, ds = \mu_s\, c_0$$

Once the profit function is determined, it is then necessary to compute the probability of beating a particular competitor with a given bid amount. This is determined by analysing the distribution of ratios, r_i=1,2,3,.......n of competitors' bids to the contractor's cost estimate based upon past bidding patterns. The distribution of r_i of a known competitor (i) is shown in figure 5.1. Thus, the probability that b_0 is less than that of the competitor is indicated by the area under the curve to the right of b_0/c_0 (shaded portion of curve). The probability that b_0 is less than the bid of competitor i is determined as follows:-

$$
\begin{aligned}
P(b_0 < b_i) &= \int_{b_0/c_0}^{\infty} f_i(r_i)\, dr \\
&= 1 - \int_0^{b_0/c_0} f_i(r_i)\, dr \\
&= 1 - F_i\left(\frac{b_0}{c_0}\right)
\end{aligned}
$$

where $F_i(b_0/c_0)$ = Cumulative distribution function of r_i evaluated at b_0/c_0.

Figure 5.1 : Probability density function of a known competitor's bid to contractor's cost ratio



Thus, the probability of beating any given competitor may be determined as described above by simply analysing the past tender bids of the competitors.

However, in a bidding situation, there is usually more than one bidder. As such, it is not only necessary to determine the probability of beating each individual competitor but also the combined probability of beating all the competitors at the same time. In this case, Friedman assumed stochastic independence of the bidding process and thus adopted the multiplication rule of probability theory to determine the probability that b_0 is less than all the bidders as follows:-

$$P[(b_0 < b_1) \cap (b_0 < b_2) \cap \ldots \cap (b_0 < b_n)]$$
$$= \prod_{i=1}^{n} \left[1 - F_i\left(\frac{b_0}{c_0}\right)\right]$$

The competitive bidding problem is thus to find out the bid, b_o^*, over all possible bid amounts, which maximises the expected profit.

$$\max E(p) = \max_{\text{all } b_0} (b_0 - \mu_s\, c_0) \prod_{i=1}^{n} \left[1 - F_i\left(\frac{b_0}{c_0}\right)\right]$$
$$= (b_0^* - \mu_s\, c_0) \prod_{i=1}^{n} \left[1 - F_i\left(\frac{b_0^*}{c_0}\right)\right]$$

For cases where the identities of the bidders are not known, Friedman suggested a distribution of the ratio of an average bidder's bid (typical bidder) to the contractor's cost estimate. This distribution is obtained by combining the bid/cost estimate (s) ratios of all bidders into a single distribution. The probability of beating an average bidder is thus derived as follows:-

$$P(b_0 < b_\alpha) = \int_{b_0/c_0}^{\infty} f_\alpha(r_\alpha)\, dr$$
$$= 1 - F_\alpha\left(\frac{b_0}{c_0}\right)$$

where $f_\alpha(\cdot)$ = density function of the average bidder; and

$F_\alpha(\cdot)$ = cumulative function of the average bidder.

b_α = bid of an average bidder.

Therefore, the competitive bidding problem for beating against n unknown bidders is expressed as follows:-

$$\max E(p) = \max_{\text{all } b_0} (b_0 - \mu_s c_0) \left[1 - F_\alpha \left(\frac{b_0}{c_0}\right)\right]^n$$

$$= (b_0^* - \mu_s c_0) \left[1 - F_\alpha \left(\frac{b_0}{c_0}\right)\right]^n$$

5.3.1.2 Other Expected Monetary Value bidding models

Since the development of Friedman's model in 1956, numerous attempts have also been made by many other researchers to develop various models to guide the decision making processes of bidders. However, most of these models have in one way or another adopted the same approach as Friedman but with various modifications. A comprehensive review comparing the differences of principal bidding models is provided by Benjamin (6) and more recently by Sundaram (15). Most of these efforts have been focussed on resolving the controversy involved in the development mechanism (probability derivation and assumptions) of past bidding models. Some have managed to refine Friedman's model while others have adopted new approaches to the bidding problem.

5.3.1.3 Differences in bidding models

Although many bidding models have been developed, they differ from each other principally in one or more of the following aspects:-

a) Derivation of profit function.

b) Derivation of probability of beating a specific competitor.

c) Combination of probabilities of beating individual competitors to determine the probability of beating all the competitors at the same time.

d) Assumptions of model.

   i) Relationship between number of bidders and job cost.

ii) Influence of factors such market conditions, job type, client type, job location and identity of competitor on the competitive environment.

(a) Derivation of profit function

The difference in profit function arises due to variations in methods adopted by various researchers in measuring the cost of work. Basically, the profit of a contract is the margin between the bid and the actual cost which is often not known until the job is completed. Thus, the key issue lies in whether the estimated cost is close to the actual cost of the job. Friedman (1) acknowledged the presence of systematic errors in engineering estimate and thus suggested a procedure (adoption of the "s" ratio as described before) for correcting this bias. However, Park (2), Gates (3), Casey and Shaffer (4), Weverbergh (16), and Capen et. al. (17) take the view that cost estimate is often correct on average, and therefore the population mean of "s" is unity with a dispersion of zero. As a result, they assumed that the true cost of the job is equal to its estimated cost. There are many other researchers who have taken different views regarding the distribution of the true cost and cost estimate. Skitmore (14) has summarised the main distribution parameters of the true cost / estimated cost distribution as presented by various modellers as shown in table 5.1.

(b) Derivation of probability of beating a specific competitor

All bidding models concede that the derivation of the probability of beating a competitor must be obtained by analysing past tender bids of the competitor. Friedman (1), Park (2), Gates (3), and Casey and Shaffer (4) have suggested fitting the data (competitor's bid / contractor's cost estimate) into a continuous function so as to determine the probability of beating a particular competitor. Morin and Clough (18) have instead utilised a discrete probability function in their OPBID model. They argued that this method eliminates any smoothing errors which may result when fitting observations into a continuous function.

The main controversy in the derivation of probability of beating a given competitor is centered on the fitting of the data into various types of distributions. A summary of the distribution parameters of various distributions as adopted by various researchers is provided by Skitmore (14) as shown in table 5.2.

Table 5.1 : Distribution parameters for true cost / cost estimate

(Source: Skitmore M., Contract bidding in construction, Longman, 1989)

Modeller	*Shape*	*Spread*	*Location*
Barnes (1971)[h]		cv 5.8%	
Barnes & Lau (1974)[a]		cv 4–15%	
Beckmann (1974)[a]	Normal		
Beeston (1974)[g]		cv 4%	
Capen *et al.* (1971)[a]	Lognormal		
Case (1972)[c]		cv 5.5%	
Cauwelaert & Heynig (1978)[a]	Uniform	± A%	
Fine (1974)[b]	Uniform	± 10%	
Fine & Hackemar (1970)[b]	Uniform	± 8–10%	
Friedman (1956)[c]	Gamma		
Gates (1967)[d]	Normal	cv 7.5%	
Griesmer *et al.* (1967)[a]	Uniform		
Hackemar (1970)[b]		± 5–15%	
Harris & McCaffer (1983)[a]	Uniform	± A%	
Leech & Earthrowl (1972)[c]	Lognormal		
Liddle (1979)[a]		± 5%	
Mitchell (1977)[a]	Normal		
Morin & Clough (1969)[c]	Symmetrical	cv 2%	1.0 (median)
Morrison & Stevens (1980)[a]		± 5–7½% (mean)	
Moyles (1973)[f]		± 5%	
Naert & Weverbergh (1978)[i]			close to 1
Oren & Rothkopf (1975)[a]	Weibull		
Park (1966)[a]		± 5%	
Rickwood (1972)[b]	Normal		
Rothkopf (1969)[a]	Weibull		1.0 (exp. val)
Rothkopf (1980)[a]	Weibull		
Rubey & Milner (1966)[a]		less than 10%	
Smith & Case (1975)[c]	Lognormal		
Smith & Case (1975)[c]	Loglogistic		
Vickrey (1961)[a]	Uniform		
Whittaker (1970)[e]	Uniform		
Willenbrock (1972)[j]			+ 3%

[a] assumed for theoretical purposes
[b] assumed for simulation purposes
[c] source of data unknown
[d] analysis of 110 USA road projects
[e] analysis of 153 UK construction projects
[f] opinion survey of UK contractors
[g] analysis of extent of agreement between UK construction estimators
[h] analysis of 160 British construction projects
[i] discussion with Dutch construction companies
[j] analysis of 20 USA road projects

Table 5.2 : Distribution parameters for tender bids

(Source: Skitmore M., Contract bidding in construction, Longman, 1989)

Modeller	*Shape*	*Spread*	*Location*
AICBOR (1967)[o]		cv 6.8%	
Alexander (1970)[d]	Normal		
Arps (1965)[d]	Lognormal		
Barnes (1971)[m]		cv 6.5%	
Beeston (1971)[i]	Pos. skewed	cv 5.2–6%	
Brown (1966)[d]	Lognormal		
Capen *et al.* (1971)[d]	Lognormal		
Cauwelaert & Heynig (1978)[a]	Uniform		
Cauwelaert & Heynig (1978)[g]	Normal		
Crawford (1970)[d]	Lognormal		
Dougherty & Nozaki (1975)[d]	Gamma		
Emond (1971)[d]	Normal		
Fine & Hackemar (1970)[b]	Uniform	cv 5%	
Friedman (1956)[a]	Gamma		
Grinyer & Whittaker (1973)[c]	Uniform	cv 6.04%	
Hossein (1977)[k]	Gamma		
Klein (1976)[a]	Lognormal		
McCaffer (1976a)[f]	Normal	cv 6.5%	
McCaffer (1976a)[n]	Normal	cv 7.5%	
McCaffer (1976a)[j]	Normal	cv 8.4%	
McCaffer & Pettitt (1976)[j]	Pos. skewed	cv 8.4%	
Mitchell (1977)[a]	Normal		
Morrison & Stevens (1980)[a]	Normal	19.1% av. range	
Oren & Rothkopf (1975)[a]	Weibull		
Park (1966)[h]	Pos. skewed		
Pelto (1971)[d]	Lognormal		
Shaffer & Micheau (1971)[p]		cv 7.65%	
Skitmore (1981a)[l]		cv 7.65%	
Skitmore (1986)[q]	Normal	cv 6.8%	
Skitmore (1986)[r]	3 param lognormal	cv 13.5%	
Skitmore (1986)[s]	3 param lognormal	cv 7.8%	
Weverbergh (1982)[a]	Lognormal		
Whittaker (1970)[c]	Uniform		1.068

[a] Assumed for theoretical purposes
[b] Analysis of an 'adequate' sample of UK construction contracts
[c] Analysis of 153 UK government construction contracts
[d] USA oil and mineral tracts – source of data unknown
[e] Assumed for simulation studies
[f] Analysis of 183 Belgian building contracts
[g] 'consistent with work of other researchers'
[h] USA construction projects – source of data unknown
[i] Large sample of PSA building contracts
[j] Analysis of 384 Belgian road contracts
[k] Analysis of 545 US civil engineering and 63 mechanical engineering contracts
[l] Analysis of 269 UK building contracts
[m] Analysis of 159 UK construction contracts
[n] Analysis of 16 Belgian bridge contracts
[o] Analysis of 213 UK motorway contracts
[p] Analysis of 50 USA construction contracts
[q] Analysis of 51 UK construction contracts
[r] Analysis of 218 UK local authority construction contracts
[s] Analysis of 373 UK construction contracts

(c) Combination of probabilities of beating individual competitors to determine the probability of beating all competitors at the same time

Probably the most controversial issue among all bidding models is that of determining the combined probability of beating all competitors. If bidding may be regarded as a random process and stochastic independence assumed, it is then possible to compute the probability of beating all competitors by simply multiplying the probability of beating each competitor (multiplication rule of probability theory). However, severe criticisms were made by various researchers with respect to this assumption of stochastic independence. Benjamin (6) argued that *"a sequence of bidding situations is not really a sequence of performances of the same experiment and each job is unique"* and thus bidding events are not truly random in the classical statistical sense. Despite this, many researchers have adopted a more pragmatic view of this assumption and argued that the data "reasonably" resemble the statistical premises.

The assumption of stochastic independence was adopted by researchers such as Friedman (1), Park (2), Morin and Clough (18) and many others. Gates (3), on the other hand, disagreed with Friedman's model and provided his own unique probability of beating all bidders. Rickwood (19), in an attempt to resolve the controversy between Friedman and Gates, developed a probability function which is basically a weighted average of Friedman and Gates based upon the extent of the variability of the cost estimate and markup. Alternatively, there are other researchers who avoided this controversy by simply developing a "lowest bidder" model. For instance, Fine (20) argued that the only competitor a contractor is interested in beating is the lowest bidder. As such, he modelled the behaviour of a contractor against the lowest bidder to obtain a single distribution. Thereafter, the probability of beating the lowest bidder may be determined directly from the lowest bidder's distribution. This approach has obvious advantage of avoiding the use of complex mathematical expressions to combine probabilities. However, it has a severe limitation as the model requires a substantial amount of data to form a "stable" distribution. The collection of such data will usually take a long time during which the bidding strategies of competitors may change dramatically, thus rendering the distribution invalid. A similar approach was also adopted by Beeston (21) in his D-curve model which monitors the winning bids of contracts. Conversely, there are also some researchers such as Broemser (7), and Wade and Harris (12) who have not assumed stochastic independence in their bidding models. Thus, it can also be observed that no definite conclusion has been reached on this aspect of bidding theory.

(d) Assumptions of current bidding models

Various assumptions were also made in the development of bidding models. Many researchers have attempted to establish relationships between bidding variables such as number of bidders, job size, client type, job type, job location and market conditions. The principal differences between the models are discussed as follows:-

i) Relationship between number of bidders and job cost

Both Friedman (1) and Park (2) have acknowledged that the number of bidders competing on any specific job is related to its job cost. They argued that larger jobs offer higher potential profit and thus should logically attract more bidders and vice versa. Park (2) has further investigated the relationship between optimum markup, cost estimate and job size as follows:-

$$(C_1/C_2)^x = (m_2/m_1)$$

$$(n_1/n_2)^x = (m_2/m_1)$$

where	C_1 and C_2	=	estimated direct cost of jobs.
	m_1 and m_2	=	markups.
	n_1 and n_2	=	number of bidders on jobs.
	x	=	an appropriate exponent.

On the other hand, Gates (3) has analysed a sample of 30 highway projects and concluded that *"there is no evidence that the number of bidders for a construction project is in any way related to the magnitude of the cost of the job."* There are also numerous attempts made by other researchers such as Wade and Harris (12), Sugrue (13), and many others to establish the relationship between number of bidders and job size but without any conclusive evidence. In a recent work by Skitmore (14), he suggested that a logarithmic linear model provides the most appropriate means of expressing the relationship between number of bidders and contract value.

ii) **Influence of factors such market conditions, job type, client type, job location and identity of competitor on the competitive environment.**

The influence of market conditions (economic conditions) on the competitive environment is investigated by researchers such as Flanagan and Norman (9), Skitmore (14), Beeston (21), McCaffer (22), deNeufville, Hani and Lesage (23) and others. Generally, most researchers tend to agree that a negative correlation exists between market conditions and the intensity of competition (usually measured by the number of bidders, bid spread or bid dispersion). That is, in a buoyant market competition is less intense, while in a depressed market bidding is more competitive among bidders.

With regard to the influence of identities of competitors, Benjamin (6), Morin and Clough (18), Wade and Harris (12) have suggested that the combination of bidders is dependent upon factors such as type of work, job size, type of client and job location. Other researchers such as Shaffer and Micheau (10), and Skitmore (14) have attempted to develop prediction models (such as logarithmic linear model) to determine the combination of bidders under various bidding conditions or the LOMARK model by Wade and Harris (12) which attempts to represent the local construction market environment in bidding.

5.3.2 Expected Utility Value bidding models

Basically, this approach was utilised by some researchers as a result of limitations in existing bidding models. The use of the Expected Monetary Value approach has been severely criticised for making simplistic assumptions about what people want and how they make decisions. All these models presume that bidders will try to maximise their profit function (which is often expressed in monetary units) and the value system of an individual is linearly related to the profit function. The validity of this assumption was first questioned by Bernoulli (24) who expressed that:-

"The determination of the value of an item must not be based on its price, but rather on the utility it yields. The price of the item is dependent only on the thing itself and is equal for everyone; the utility, however, is dependent on the particular circumstances of the person making the estimate. Thus, there is no doubt that a gain of one thousand ducats is more significant to a pauper than to a rich man though both gain the same amount."

As a result, modifications to existing models were made by researchers such as Benjamin (6), deNeufville, Hani and Lesage (23), Willenbrook (25), Carr (26), and Ibbs and Crandall (27) incorporating the concept of Utility theory in bidding models to represent the attitude of bidders. The development of Expected Utility Value bidding models is similar to the Expected Monetary Value approach except that the competitive bidding problem is being expressed in terms of maximising the expected utility of the bidder.

5.3.3 Other approaches to competitive bidding

Besides the two main approaches described above, there are many other researchers who have employed a variety of other methods and techniques to enable bidders to manage risks in bidding more effectively and efficiently. The main alternatives include cash flow analysis (15, 28), portfolio theory (29), game theory (30, 31, 32, 33), tender bid pattern analysis (2, 9, 14, 20, 21, 22, 35, 36, 37, 38, 39, 40) and simulation methods (19, 20).

5.4 Limitations of current bidding models

From the review of bidding literature, it is noticed that extensive research has been carried out both in the Construction and Operations Research industries on competitive bidding strategy. Disappointingly, there is still no clear and conclusive evidence showing their practical applications in the industry. Furthermore, there is a lack of guidelines given to contractors to enable them to apply such knowledge in practice. As such, many contractors are still relying on their intuitive judgement and experience to make decisions in competitive bidding. The main reasons for the apparent lack of application of the current bidding models are described as follows:-

a) Lack of consensus among bidding experts

The most obvious reason for the limited application of bidding models is the general lack of consensus among various bidding experts with regard to the basic concept of bidding theory. As discussed earlier, many criticisms were made of many different approaches and models developed by various researchers. There is very little evidence of agreement among researchers on the fundamental issues (such as derivation of profit function and probability of beating competitors) involved in the development of bidding models. As a result, numerous bidding models were developed thus causing much confusion to contractors in selecting the appropriate model. This general lack of agreement among researchers has also made contractors sceptical about the reliability of the existing prediction models.

b) Data limitations

Most bidding models involve statistical and mathematical analyses requiring a reasonably large sample size of tender bid data in order to produce reliable and accurate predictions. However, in practice most contractors only tender for a limited number of jobs and, furthermore, they meet different competitors in different bidding situations. Thus, it is difficult to obtain adequate data to measure the relative bidding performance of the contractor and his competitors so as to fit into probability density function. Furthermore, in certain bidding situations, it is difficult to ascertain the identities of competitors, thus making it more difficult to provide accurate analysis and predictions. This problem of data limitations was recognised by a number of researchers such as Friedman (1), Whittaker (5), Benjamin (6) and Weverbergh (16). Friedman introduced the concept of the/an "average or typical" bidder by aggregating the tender bids of all competitors into a single probability density function so as to model the collective behaviour of competitors. Whittaker adopted a similar approach by standardising all bids in a contract by their bid means, and then combining these standardised bids into one distribution. However, this method has been criticised by Curtis and Maines (41) as being statistically invalid. There are some researchers (19, 20) who have attempted to resolve this deficiency by means of computer simulation.

c) Insensitivity of models to market conditions

Many existing bidding models have been criticised for making over simplistic assumptions about bidding situations. Most researchers considered bidding in isolation and failed to appreciate the influence of changing market conditions on the competitive environment and the impact of such changes on the behaviour of bidders. Some researchers (12, 23) have managed to incorporate the influence of market factors in their models but without much success. Flanagan and Norman (9) have also suggested that tendering should be modelled as a sequential process whereby the success or failure of a bid submission will affect the bidding level of future contract opportunities.

d) Assumptions on the modelling of competitors' behaviour

Perhaps the most controversial issue in bidding models is that of the modelling of competitors' bidding behaviour. Most models assume that competitors will follow the same bidding patterns in the future as in the past. Obviously, this assumption does not hold in practice as competitors are known to change their bidding strategies according to different bidding situations. As pointed out by Beeston (21), if a competitor changes his strategy, all past data about his bidding behaviour will be rendered invalid or misleading, thus defying any accurate predictions of his future behaviour. This notion is further confirmed by McCaffer (22) who found that some contractors do not behave consistently as indicated by his CUSUM analysis of individual contractors. Thus, if competitors do not behave consistently enough to allow any reasonable prediction of their behaviour, this would render many current bidding models invalid. However, Park (2) and Beeston (21) argued that in the absence of other information, past data still provides the best possible guide to monitoring bidding performance of competitors.

e) Theoretical nature of models

Another reason for the limited application of most bidding models is the highly theoretical nature of these models. Very often, complex mathematical expressions or statistical analyses are used in the development of these models. These techniques are usually not familiar to contractors thus reducing their potential practical applications.

Thus, it can be seen that despite the presence of numerous bidding models, they are seldom utilised by contractors in the industry. Investigations by Stark (42), Wong (43) and Lansley (44) have found that most contractors do not favour the use of bidding models and are still relying upon their intuitive judgement and experience to make decisions in competitive tendering. The apparent failure of most bidding models is mainly attributed to the high complexity and difficulty involved in modelling the competitive problem. This observation is made by several researchers such as Flanagan and Norman (9), Skitmore (14) and Woodward (45). As described by Woodward, the whole subject of bidding and tendering *"appears to defy analysis and is cloaked in a certain amount of mystery."* According to Woodward, there are two principal reasons contributing to this phenomenon. Firstly, there are too many variables involved in a competitive bidding situation and these variables interact in a highly complex manner thus making it difficult to establish any meaningful relationships among the factors. Secondly, this is a highly sensitive area of investigation as it concerns the survival of the firms. Many contractors are thus unwilling to provide or share information (tender bid information and strategy) thus making data collection a tedious and difficult process.

From the review of bidding literature, it is observed that many quantitative (mathematical) models have failed to model the bidding process accurately. The main reason for such failures is well summarised by Flanagan and Norman (9) as follows:-

"Price prediction is not a precise science, but an art which involves intuition and expert judgement"

This view is also shared by Whittaker (5) who acknowledged that *"mathematics is unlikely to supersede judgement entirely."* Thus, from the above review, it can be concluded that *"tendering is not a precise science and the process of risk management in competitive bidding should include the application of both scientific and intuitive approaches in order to attain a satisfactory solution to the problem."* This view is also supported by Skitmore (14) who commented that *"what is needed is a model that reflects the truly pivotal factors in the environment being modelled, especially with regard to the types and amounts of available data and the ability to process this information rapidly enough to be useful to the decision maker."*

Thus, this study aims to provide an integrated approach to risk management in competitive bidding. It proposes to develop a decision support and risk management system which will provide both quantitative (tender bid analysis and bidding model) and qualitative (identify major risk factors and risk perception of bidders) information to enable contractors to make decisions more effectively and efficiently in competitive tendering.

CHAPTER SIX

DECISION SUPPORT AND RISK MANAGEMENT SYSTEM

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DECISION SUPPORT AND RISK MANAGEMENT SYSTEM

6.1 Introduction

This chapter describes the concepts of Decision Support Systems (DSS) and discusses their potential applications in competitive tendering to support the decision making processes of contractors. Various definitions of the Decision Support System are reviewed, highlighting the essential ingredients of the system. Besides this, the main development process of the proposed decision support and risk management system is described, identifying the principal tools and techniques adopted for the system. Finally, the main modules of the system are described, highlighting the key features of each module.

6.2 Conceptualisation of Decision Support and Risk Management System (DSRMS)

The concept of the Decision Support System (DSS) was first introduced by Scott Morton (1) in the early '70s when he was investigating management decision systems. Since then, much research effort has been concentrated in this area, especially in the fields of decision making and information technology, with attempts to develop interactive computer based systems, aimed at helping decision makers to solve unstructured problems. As acknowledged by Keen and Scott Morton (2), managers generally face two main types of decision tasks in an organisation namely: (i) structured tasks, and (ii) unstructured tasks. They defined unstructured decision tasks or problems as *"those tasks that require a manager to make situational value judgements from a personal frame of reference"* while structured tasks refer to activities which can be automated to a certain extent in order to achieve the "best way" of doing them. Therefore, this implies that any decision support system must be capable of identifying the structured and unstructured tasks of a manager. Consequently, computer automation may then be utilised to perform the structured tasks while allowing the manager to exercise his judgement to resolve the unstructured problems, thus improving his decisions.

Besides resolving unstructured problems, Decision Support Systems are also commonly applied in certain decision situations. Mittra (3) has identified various characteristics of a situation where Decision Support Systems are needed or useful, as described below:-

a) In situations where there exists a large database which is so large that managers find it difficult to access and make conceptual use of it.
b) The decision situation necessitates the manipulation and computation of the data to arrive at a solution.
c) There is considerable time pressure imposed on the decision maker to provide a solution to the problem.
d) It requires judgement to decide upon available alternatives by asking many "what if" questions.

From the discussion in chapters three and five, it is observed that the nature of the problem in competitive bidding fits into the situational characteristics which require a decision support system. First of all, the task of tendering (pricing of a tender bid) is a highly complex and unstructured problem which requires considerable judgement from contractors. Secondly, there is an abundance of information available both inside and outside a contractor's organisation where contractors either encounter difficulties in gaining access to the data or fail to understand the data in their existing form (often not organised in any understandable form as observed by Cussack (4)). Furthermore, there is often considerable time pressure imposed (by the client) on the contractors to make decisions in competitive bidding. Thus, it can be seen that contractors are often faced with bidding situations where they need information rapidly to support their decisions, and at the same time require critical judgements to arrive at a solution. The viability of applying the concept of DSS to competitive bidding was also acknowledged by Skitmore (5) who commented as follows:-

"A decision support system is a management information system that has some processing capacity to help the decision maker use other information................................ The nature of the contract bidding problem suggests that a decision support system may well provide a viable approach."

Thus, from the above discussion, it can be concluded that competitive bidding is a complex and unstructured task requiring both information support and judgement from contractors in order to arrive at a satisfactory solution. As such, this study aims to develop a decision support and risk management system (DSRMS) which will provide a systematic framework supplying both quantitative and qualitative information to support and improve the decision making processes of contractors in competitive tendering.

6.3 Definition of terms in Decision Support System (DSS)

There are several definitions of DSS as put forward by various researchers. For instance, Scott Morton (1) defined DSS as:-

"an interactive computer based system which helps the decision maker to utilise data and models to solve unstructured problems."

A similar definition of DSS as suggested by Mittra (3) is that:-

"A decision support system is a computer based information system that helps a manager make decisions by providing him or her all the relevant data in an easily understandable form."

Another definition of DSS is provided by Sprague and Watson (6) as follows:-

"DSS is defined as :-

- *a computer based system*
- *that helps decision makers*

- *confront ill-structured problems*
- *through direct interaction*
- *with data and analysis models."*

As observed by Sprague and Watson (6), the main objective of a DSS *"must be viewed in terms of the ability of the information systems to support the improved performance of people in organisations."* This view is also shared by Keen and Scott Morton (7) who emphasised that DSS *"supports, rather than replaces managerial judgement."*

Thus, from the above definitions, it can be identified that a DSS is basically a computerised information system that **supports** the decisions of managers in resolving unstructured problems.

As discussed in chapter five, one of the principal causes of failure of current bidding models is that most of these models fail to understand that tendering is not a precise science and that it involves considerable judgement from contractors. It is basically an unstructured decision task of contractors and thus cannot possibly be formulated in a "structured manner" as suggested by many researchers to obtain an "optimum solution". As such, this study adopts the view that the problems of competitive bidding should be treated as unstructured tasks which require information support and judgement from contractors in order to achieve a satisfactory solution. It is also a task that demands considerable entrepreneurial judgements (business acumen) on the part of the decision-makers.

6.4 Characteristics of Decision Support System

There are several unique characteristics which are inherent to a DSS that must be understood prior to the development of the system. The main features as identified by Alter and Keen (8) are listed as follows:-

a) They are usually aimed at less structured, underspecified problems that upper managers typically face.

b) They utilise a combination of models or analytic techniques with traditional data access and retrieval functions.

c) They focus on features which make them easy to use by means of an interactive manner.

d) They have high flexibility and adaptability to accommodate changes in the environment and the decision making approach of the decision maker.

6.5 Development of the proposed Decision Support and Risk Management System (DSRMS)

There are basically five main stages involved in the development process of the proposed decision support and risk management system for competitive bidding in refurbishment work. The principal activities involved in each stage are described below highlighting the main considerations and criteria adopted in designing the system.

a) Problem definition and feasibility study

The first task in developing any DSS system usually involves the searching, identifying and defining of the problem to be solved by the system. This process entails the gathering of facts by reviewing documents, reports, manuals or by interviewing the people involved in the decision process. In this study, this process of problem searching and definition was carried out by reviewing past bidding literature, criticisms of various modellers and interviewing of directors and estimators (decision makers of bidding problem) of refurbishment firms.

With regard to feasibility analysis, three main aspects of the system are considered namely: (i) economic feasibility, (ii) technical feasibility, and (iii) operational feasibility. In order to be practically functional and operational, the proposed system must achieve a delicate balance of the above three criteria in terms of cost of implementing, operating and maintaining the system.

Thus, the main objective of the proposed DSRMS as discussed in chapter one is as follows:-

"To provide a decision support and risk management system that will supply both quantitative (tender bid analysis) and qualitative information (risk perception of contractors) to support and improve tendering decisions of contractors."

The main information requirements of contractors in competitive bidding in refurbishment work have been identified as follows:-

a) Information on tender bid patterns (population analysis).
b) Information on tender bid patterns (sub-population analysis).
c) Competitive pattern of tender bids.
d) Relationship between bidding variables.
e) Information on bidding performance of contractor.
f) Information on bidding performance of competitors.
g) Bid prediction model.
h) Identification of major risk factors.
i) Information on risk perception of contractors.

b) System analysis

In this phase, in-depth investigations were conducted to determine the capabilities required for the proposed DSRMS. The overall objective of the system is analysed so as to enable the main system to be sub-divided into sub-systems which are linked together in a logical way. Detailed investigations were also performed to determine the main deficiencies of the existing system (tendering decision processes of contractors). Thus, essentially this phase involves analysing and understanding the competitive problems (information gap) faced by contractors in practice and determining the capabilities which must be built in the proposed system in order to produce the required information to support decisions. In this study, the main requisite capabilities of the system are identified as follows:-

i) Capacity to store large databases.

ii) Statistical and mathematical analyses.

iii) Data retrieval functions.

iv) Graphics and report facilities.

c) Preliminary system design

Once the main objectives of the system are determined and the required capabilities identified, the next step is to determine how to achieve the proposed system capabilities. Essentially, this stage involves the specification of input data, processing ability and output data of the system. Very often, the details of output information are provided by the users (contractors in this instance) while the input requirements are specified by both the system designer and users. The link between the input and output component is provided by the processing component of the system. This process usually entails the use of flow diagrams to develop the logic of the system in terms of data processing and output requirements. Thus, the input, output and processing requirements of the proposed DSRMS as specified as follows:-

a) **Input component**

- Tender bid records of contractors.
- Information of risk perception of contractors.

b) **Processing component**

- Statistical analyses.
- Mathematical modelling.
- Risk perception analysis.

- Data management capabilities.

c) **Output component**

- Information as described in the problem definition phase.

d) Detailed design

This consists of the detailed design of the system and involves specifying the system level design and the program level design. The main activities in this phase are listed as follows:-

i) Selection of both hardware and software.
   - Heriot-Watt University, DEC VAX 8700.
   - Micro-computer for Flexigrid analysis.
   - SPSS-X and Minitab statistical packages.
   - FORTRAN programming.
   - SPSS-X data management procedures.

ii) Organisation and classification of data.

iii) Design of data input mechanism.

iv) Development of computer programs.

v) Specification and description of the proposed DSRMS.

e) Implementation, maintenance and evaluation

This last phase of the development process consists of implementing the system and testing its reliability and accuracy. The main activities include testing and debugging programs, provision of user documentation, user training, implementation schedule and program. Once a system is implemented, maintenance operations must be carried out for the upkeep of the system.

6.6 Description of Decision Support and Risk Management System

The proposed decision support and risk management system consists of six modules as shown in figure 6.1. The first five modules (as set up in the DEC VAX 8700) provide quantitative information which describes the bidding characteristics of tender bids in refurbishment contracts (lump sum contracts) and information on the bidding performance of contractors. All statistical and mathematical analyses were performed using the SPSS-X and Minitab statistical packages, and FORTRAN programs. The last module of the system provides information which measures the risk perception of contractors (directors and estimators) in competitive tendering. Information in this module is provided by means of a specially developed program called Flexigrid as described in chapter nine.

The main features and capabilities of each module are described as follows:-

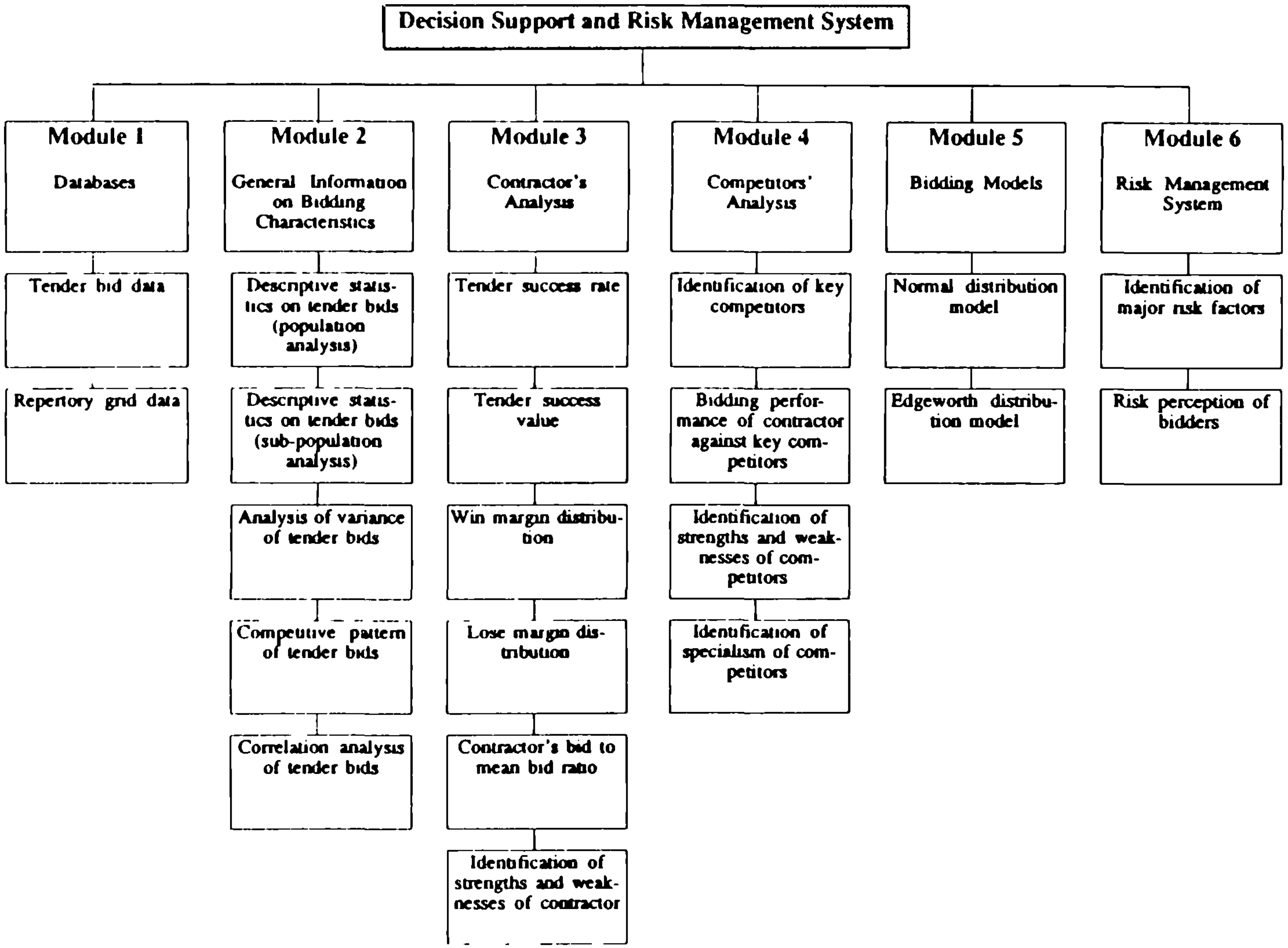
6.6.1 Module One - Databases of tender bid records and Repertory grid data

This module contains the databases of the system. There are two primary databases namely: tender bid database and Repertory grid database in the system. The tender bid database contains information such as year of tender, client type, job type, job size, job location, number of bidders, identities of bidders and their respective tender bids. This information is input into a fixed data format database (using SPSS-X on the DEC VAX 8700) which is described in chapter nine. On the other hand, the Repertory grid database is set up on a micro-computer system. It contains information on the personal risk constructs of directors and estimators in competitive bidding for refurbishment contracts.

6.6.2 Module Two - General information of bidding characteristics

This module provides general information on the bidding characteristics of refurbishment contracts (lump sum contracts). Descriptive statistics of major bidding variables such as number of bidders, job size, job type, job location and client type are computed. Besides

Figure 6.1 : Decision support and risk management system for competitive bidding in refurbishment work



this, various measures of tender bid dispersion and level of competitiveness of bids are also determined. The main purpose of this module is to provide information which will enhance the understanding of contractors in competitive bidding. For example, information on the number of bidders and bid dispersion for specific job types will enable contractors to understand the general level of competitiveness of these markets. Such information provides vital feedback to contractors and also assists them to formulate appropriate bidding strategies for future contracts.

In this module, various SPSS-X statistical procedures were adopted in order to provide the necessary information describing the bidding characteristics of different bidding situations. The main SPSS-X procedures utilised are listed below:-

a) Descriptive statistics.
b) Breakdown analysis and one-way analysis of variance.
c) Cross-tabulation.
d) Scatterplot and correlation analysis.

Descriptive statistics such as mean, standard deviation, minimum, maximum, skewness and kurtosis are used to describe the characteristics of tender bids in refurbishment work. The SPSS-X BREAKDOWN command provides facilities for analysing bidding characteristics of tender bids under different bidding situations such as job type or job size. The CROSS-TABS procedure identifies competitive patterns of tender bids by plotting the frequency of bids on any two specified bidding variables. For example, the frequency of bids may be plotted on a table defined by job size and bid RD thus displaying how tender bids are distributed for different job sizes and bid RD. The scatterplot and correlation analysis basically measures the degree of association between different bidding variables. Based upon the information as contained in the tender bid database, the main information outputs of this module are listed as follows:-

a) Descriptive statistics of tender bids (population analysis).

b) Descriptive statistics of tender bids (sub-population analysis).

c) One-way analysis of variance of bidding variables.

d) Competitive pattern of tender bids.

e) Correlation analysis of bidding variables.

6.6.2.1 Descriptive statistics of tender bids (population analysis)

The following provides a list of measures which are adopted to describe the bidding characteristics of tender bids in refurbishment contracts.

a) General information about bidding characteristics

- i) Distribution of number of bidders per contract.
- ii) Distribution of job size.
- iii) Distribution of job type.
- iv) Distribution of job location.
- v) Distribution of client type.

b) Measures of tender bid dispersion

- i) Bid range.
- ii) Bid RD.

c) Measures of level of competitiveness

- i) Bid spread ("Money left on table").
- ii) Skewness of bid.
- iii) Kurtosis of bid.

6.6.2.2 Descriptive statistics of tender bids (sub-population analysis)

The sub-population analysis involves the sorting of tender bids into specific bidding variables such as job type or job size and then determining the bidding characteristics of the bids for each category. For example, the tender bid records may be grouped into different job types so that the mean number of bidders, bid range, bid RD and skewness may be determined for each category of job type. Such information provides useful feedback to contractors and also enhances the understanding of the contractors with respect to their bidding environment. Descriptive statistics of tender bids were determined for the following sub-population analyses:-

i) Analysis of tender bids by year of tender.
ii) Analysis of tender bids by job type.
iii) Analysis of tender bids by job size.
iv) Analysis of tender bids by client type.
v) Analysis of tender bids by job location.
vi) Analysis of tender bids by number of bidders.

Besides this, statistical analyses were also performed to determine the variability of bidding variables among different job characteristics. One-way analysis of variance tests were conducted to test whether the population means of bidding variables such as bid RD, bid range, bid spread and number of bidders are equal for different categories of job type, job size, year of tender, job location and client type. The main objective of this analysis is to determine whether bidding characteristics of refurbishment contracts are different in various bidding situations. For instance, the dispersion of bids as measured by the bid RD or bid range may differ for different job types or job sizes. Such feedback provides useful specific market information to contractors particularly for those who either specialise in and/or only operate in specific refurbishment markets (for instance, specific job type, client type or job size). Thus, the above analysis provides invaluable information which will enable contractors to have a better understanding both of their existing competitive environment as well as their potential market sectors.

6.6.2.3 Competitive pattern of tender bids

The competitive bidding pattern of the tendering process is identified by using the CROSSTABS procedure in the SPSS-X system. This procedure enables the frequency of tender bids to be tabulated according to any two bidding variables. For instance, it is possible to display the distribution of tender bids (frequency of bids) for different numbers of bidders in different job sizes. This provides a visual representation of tender bid distribution as defined by different bidding characteristics, thereby displaying specific patterns of tender bids.

In this analysis, the bid RD (measure of dispersion) and bid spread (measure of level of competitiveness) were selected to determine the competitive patterns of tender bids under different bidding situations. The main rationale for choosing the bid RD instead of the bid range is that bid RD provides a better and more robust measure of bid dispersion and is not adversely affected by extreme values of observations (tender bids). Similarly, the bid spread is also a better measure for indicating the level of competition and has been commonly adopted by many other researchers.

In order to perform the cross-tabulation of tender bids, it is necessary to classify the bid RD and bid spread into discrete categories as illustrated in tables 6.1 and 6.2 respectively.

Table 6.1 : Classification of bid RD

BID RD (%)	CATEGORY
0 to 3	1
3 to 6	2
6 to 9	3
9 to 12	4
12 to 15	5
15 to 18	6
Over 18	7

Table 6.2 : Classification of bid spread

BID SPREAD (%)	CATEGORY
0 to 2	1
2 to 4	2
4 to 6	3
6 to 8	4
8 to 10	5
10 to 12	6
12 to 14	7
Over 14	8

6.6.2.4 Correlation analysis of bidding variables

The main purpose of this analysis is to measure the strength of linear relationship (if any) of various bidding variables so as to develop prediction models. The SPSS-X PLOT procedure was adopted to determine the degree of association between various bidding variables (quantifiable variables only) such as number of bidders, job size, bid range, bid RD, skewness and kurtosis. The strength of linear association was measured using the Pearson Product Moment Correlation Coefficient.

6.6.3 Module Three - Contractor's analysis

This module provides a framework which enables a contractor to monitor and measure his bidding performance. It determines the tender success rate of a firm and provides a mechanism for monitoring the bidding performance of a contractor against his respective competitors. Besides this, an information retrieval system was also incorporated whereby past tender bid records of a contractor could be retrieved rapidly, displaying information about the bidding performance of the contractor under various bidding situations. For example, it is possible to find out the tender success rate, win/lose margin and competitiveness of a contractor's bids for specific job types such as office or residential buildings.

The main criteria for measuring and monitoring the bidding performance of a contractor are listed below:-

6.6.3.1 Bidding performance of contractor

a) Tender success rate

The tender success rate measures the number of contracts won by the firm out of the total number of bids submitted by the firm over a specified period. It is determined by expressing the number of successful bids as a percentage of the total number of contracts submitted by the firm as illustrated below:-

Tender success rate = (Total no. of successful bids) 100 / (Total no. of bids submitted)

b) Tender success value

The tender success value measures the total value of jobs won by the firm over a specified period. It is determined by expressing the total value of contracts won by the firm as a fraction of the total value of all contracts tendered by the firm. By measuring the total value of contracts secured by the firm at a certain point of time, contractors are able to monitor the progress of their firm in achieving their targeted turnover. The tender success value is computed as follows:-

Tender success value = (Total value of successful bids) 100 / (Total value of bids submitted)

c) Win margin distribution

The win margin distribution provides a measure of the contractor's bidding efficiency. It determines the extent to which a contractor has succeeded in a contract. Ideally, contracts should be won with a minimum win margin so as to achieve higher profitability. However, in practice most contracts are secured with a win margin ranging from 0% to 58% (see figure 9.8). If contracts are consistently secured with high win margins, this would indicate poor bidding efficiency of the contractor as he has *"left too much money on the table"* (a term commonly used to describe win margin). On the contrary, contractors who manage to secure contracts with consistently low win margin may be considered to have attained high bidding efficiency. The win margin of a bid is calculated by expressing the difference between the second lowest bid and the winning bid of the contractor as a percentage over the contractor's bid as shown below:-

Win margin = (Second lowest bid - Contractor's bid) 100 / (Contractor's bid)

6.6.3.2 Level of competitiveness

a) Lose margin distribution

The lose margin basically determines the margin by which a contractor has lost a contract. It is computed by expressing the difference between the contractor's bid and the lowest bid as a percentage of the contractor's bid in that contract. This margin enables a contractor to measure the competitiveness of his bids. Murray (9) in his study of competitive bidding in 1980 also adopted this measure. As acknowledged by Murray, the percentage of a bid above the lowest bid provides an indication of the competitiveness of a bidder. An increase in percentage being equated with a lack of desire to win the contract and vice versa. Thus, by analysing the lose margin distribution of past contracts, a contractor will be able to monitor the competitiveness of his tender bids. The lose margin is computed as follows:-

Lose margin = (Lowest bid - contractor's bid) 100 / (Contractor's bid)

b) Contractor's bid to mean bid ratio

This ratio measures the variation of a contractor's bids to the mean of all bids submitted for each contract. Generally, a high ratio would indicate that the contractor's bid is above the bid mean (mean of all bids in that contract) and thus would have a lower probability of success. While a low ratio would mean that the contractor's bid has a higher chance of success. This ratio is expressed as follows:-

Contractor's bid to mean bid = (Contractor's bid) 100) / (Mean bid)

6.6.3.3 Identification of strengths and weaknesses of a contractor

This section provides a framework which enables a contractor to conduct a tender performance audit so as to monitor and improve his bidding performance. It identifies the strengths and weaknesses of the firm in competitive bidding by analysing the bidding characteristics of both successful and unsuccessful bids of the firm. From the tender bid database in the DSRMS, it is possible to determine the bidding performance of a contractor under various bidding situations such as different job type or job location.

The identification of the competitive strengths and weaknesses of a contractor is performed by relating the job characteristics of past contracts to the bidding performance of the contractor, and monitoring the performance of the contractor under various bidding situations. The first stage is performed by simply listing out the job characteristics such as job number, date of tender, number of bidders, job size, client type, job type, job location and win/lose margin of the contractor. Similarly, the bidding performance of a contractor under various bidding situations may be listed.

6.6.4 Module Four - Competitors' analysis

Module 4 provides information describing the bidding behaviour of competitors of a contractor. This module enables a contractor to identify his key competitors (frequently encountered competitors) and provides a framework for monitoring the bidding performance of these key competitors. Through the review of past bidding literature and interviewing of refurbishment contractors, the main information requirements for monitoring competitors' behaviour are as follows:-

i) Identification of key competitors.
ii) Relative performance of contractor and his key competitors.
iii) Identification of competitive strengths and weaknesses of key competitors.

6.6.4.1 Identification of key competitors

The first step in the competitors' analysis involves the identification of the key competitors of a contractor. The main criterion adopted to distinguish key competitors from other bidders is by means of tender bid encounter. By analysing the frequency of encounters between a contractor and his respective competitors, it is possible to identify a number of competitors with which a contractor often competes. Once the key competitors are identified, a contractor can then measure the bidding performance of his firm against these competitors. The tender success rate and win/lose margin may be computed to determine the competition power of the contractor against his key competitors.

The main performance indicators for measuring the relative performance of a contractor and his key competitors is the win/lose margin. The win margin of a contractor against his key competition measures the margin of difference between the contractor's bid and his competitor, irrespective of whether the contractor has won the contract or not. As such, this measure determines the relative competitiveness of bids between a contractor and his competitors. A consistently large win margin would indicate that a contractor's bids are more competitive than his competitors and vice versa. Similarly, the lose margin measures the margin by which he has lost to his competitors. The computation of both the win and lose margin of a contractor is illustrated as follows:-

Win / lose margin = (Competitor's bid - Contractor's bid) 100 / (Contractor's bid)

Thus, by monitoring the performance of key competitors, a contractor will have a better understanding of the bidding behaviour of his competitors. Furthermore, this information provides additional competitive advantage to a contractor as he is able to formulate an appropriate bidding strategy to increase his chance of success.

6.6.4.2 Identification of strengths and weaknesses of key competitors

Besides monitoring the relative bidding performance of a contractor and his key competitors, this module also identifies the strengths and weaknesses of key competitors. This is performed by analysing the characteristics of past contracts won by each respective competitor. From the tender bid database, it is possible to retrieve past contracts in which a contractor and his key competitors were in competition. In doing so, a contractor will be able to monitor the performance of his firm against his key competitors under different job characteristics, such as different job types or job sizes. Thus, by simply analysing the past contracts of key competitors, useful information may be obtained to increase the efficiency of bidding strategies of contractors.

6.6.4.3 Identification of speciality of competitors

As we are aware, most contractors have different capabilities and capacities. Furthermore, many contractors tend to specialise or focus their business activities in different market sectors of the refurbishment market such as different job types or job sizes. This observation is also acknowledged by Murray (9) who mentioned that most contractors tend to specialise in certain types of construction or buildings and would not compete in other types of construction. Thus, it would be useful if it is possible to identify the specialties or interests of contractors in the refurbishment market. One way of achieving this is to determine the identities of contractors who are frequent lowest bidders for contracts with various job characteristics situations. From the tender bid database, it is possible to group the tender bids into various bidding situations such as different job types (for instance, industrial or residential) or job sizes so that the identities of contractors with the highest number of lowest bids can be determined.

Thus, the identification of contractors with frequent lowest bids for various bidding situations also provides vital market information to contractors in understanding the keenness or desire of other contractors when tendering for specific jobs.

6.6.5 Module Five - Bidding models

This module contains two bid prediction models namely: the Normal distribution model and the Edgeworth distribution model. From the analysis of 1350 tender bids from the database, tender bids are fitted into either a Normal or Edgeworth distribution for the purpose of predicting the probability of success when submitting a tender bid. The main parameters required for the application of the models are (i) the contractor's cost estimate of the proposed contract, and (ii) the ratio of the contractor's cost estimate and bid mean of past contracts. Using a total of 1350 tender bids, this module determines the distribution characteristics of tender bids in refurbishment contracts. From the analysis, two bidding models were developed which enable a contractor to predict the probability of success of a tender bid.

6.6.6 Module Six - Risk management system

This module provides a systematic framework for identifying and evaluating pertinent risk factors in competitive bidding. Significant risk factors which affect the pricing decisions of contractors are identified by means of a survey questionnaire. A well established psychological technique (Repertory Grid) is adopted for identifying the major risk constructs (risk perception) of directors and estimators when they are assessing risks in competitive tendering. Thus, this module provides qualitative information which enables contractors to understand the important risk factors involved in tendering for refurbishment contracts, thereby assisting them to manage risks more effectively and efficiently.

In conclusion, the proposed decision support and risk management system provides an integrated approach to risk management in competitive bidding. This objective is achieved by combining various items of information required by contractors during tendering into a computerised information system capable of utilising a variety of statistical and mathematical tools so as to produce invaluable information to support the decision making processes of contractors.

CHAPTER SEVEN

RESEARCH METHODOLOGY

CHAPTER SEVEN

RESEARCH METHODOLOGY

7.1 Introduction

This chapter describes the main research methodology adopted for this study. It sets out the main criteria and considerations made when selecting the most suitable research approach to develop the decision support and risk management system. Various methodological issues and alternative research methods are discussed highlighting the advantages and limitations of various research approaches. This is followed by an explanation of the main reasons for choosing the selected research approach. The research strategy is also described together with the justification for employing various types of data collection techniques and sample size selected.

7.2 Selection of research methodology and strategy

From the literature review of past work relating to competitive bidding, it is observed that many researchers have adopted different research approaches to develop various bidding models to aid contractors to manage the risks involved in competitive bidding. The most popular research method is that of Archival Research approach whereby past tender bid records of contractors are collected and analysed to determine the bidding behaviour of contractors. This is a well established technique which has been employed by researchers such as Friedman (1), Gates (2), Park (3), McCaffer (4), Skitmore (5) and many others.

Thus, in deciding on the most appropriate research methodology, this researcher has adopted the guidelines of past research work and the systematic research methodology framework (figure 7.1) as suggested by John W. Buckley, Marlene H. Buckley and

Hung Fu Chiang (6).

As illustrated in figure 7.1, this procedure provides a systematic and logical approach which enables a researcher to examine the options available in selecting a research methodology. It maps out the available alternative strategies and guides the researcher by asking the appropriate questions. In addition to the above guidelines, this researcher has also considered the following selection criteria when choosing the research methodology for this study.

a) The research approach must be capable of collecting adequate tender bid data so as to provide accurate information describing the bidding characteristics of refurbishment work (lump sum contracts). The data collected should span over several years so that bidding trends of contractors may be determined.

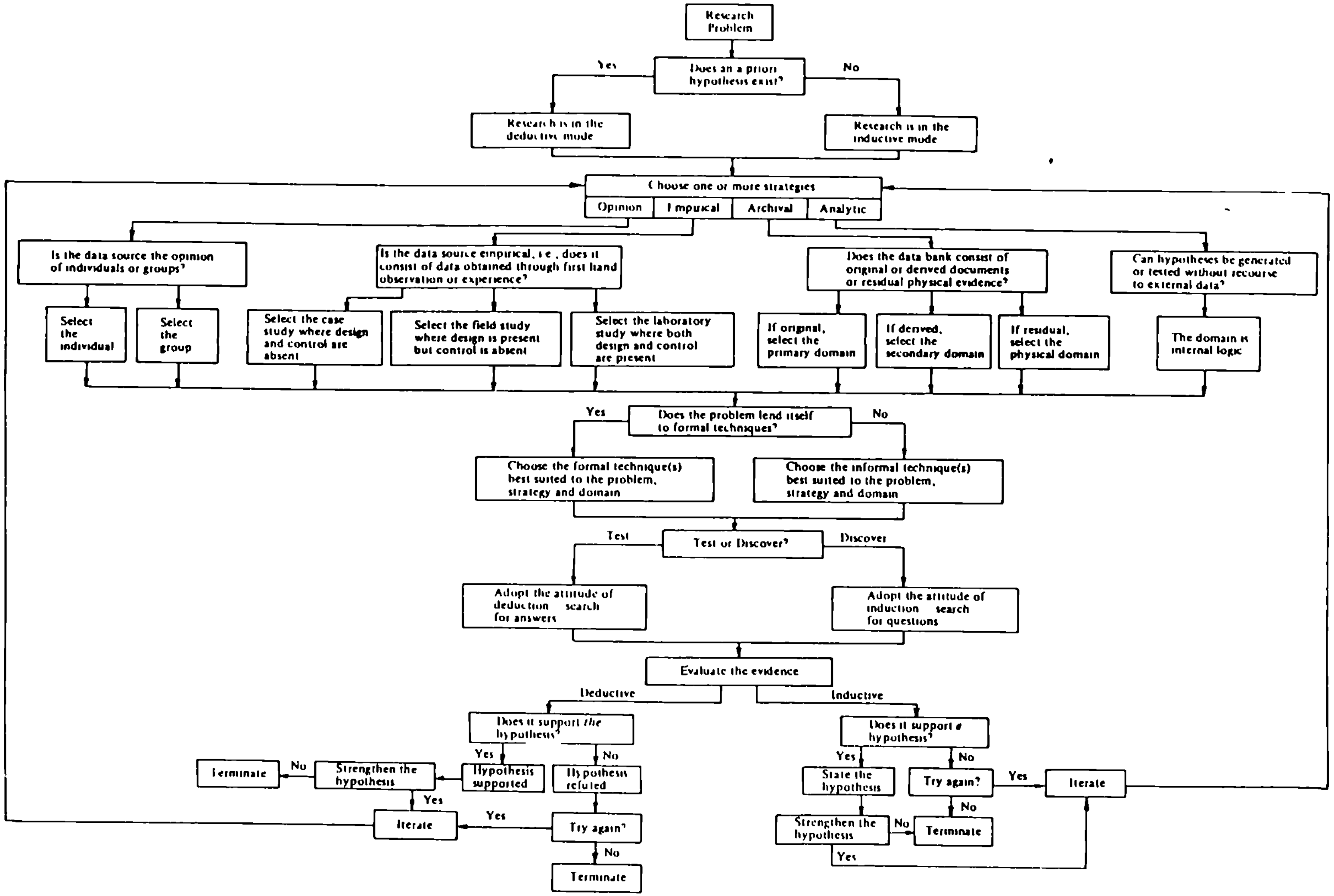
b) The data must be collected randomly from a statistically representative sample of refurbishment contractors. Furthermore, the selected data collection techniques must be free from bias arising from sources such as sampling using a non-random method, sampling frame bias or lack of response from sampling units in the sample.

c) It must also provide a means for measuring the risk perception of contractors under different bidding situations.

d) Due to the high sensitivity of the data (tender bid records and risk perception of contractors), the adopted approach must provide accurate and reliable research instruments for the collection of the required information.

Figure 7.1 : Flowchart for the selection of research methodology.

(Source : John W Buckley, Marlene W Buckley and Hung Fu Chiang)



There are four main types of research methodologies which may be applied to problem-solving in different situations as described by John W. Buckley, Marlene H. Buckley and Hung Fu Chiang (6) as follows:-

a) Opinion Research.
b) Empirical Research.
c) Archival Research.
d) Analytical Research.

A) Opinion Research

In this method, the researcher seeks to obtain information relating to the views, judgements or opinions of other people with respect to a research problem. This approach is commonly used in opinion polls associated with government election. The main data collection techniques for this method include survey research, personal interview, the Delphi method and brainstorming.

The main advantages of this research methodology are as follows:-

a) It is most appropriate for research on attitudes, impressions, opinion, beliefs and judgements of people.
b) Large samples can be surveyed thereby providing more representation of the population.
c) It is simple to devise and administer and often consists of questionnaires and interviews.
d) The data collected is capable of being analysed by a variety of standard statistical procedures thus facilitating analysis.

Its main limitations are as follows:-

a) It may suffer from methodological deficiencies such as (i) biases inherent in the design of survey instruments, for example prior selection of questions and response sets, (ii) systematic biases in the way in which the respondents answer the questions, for instance biases between favourable or unfavourable, or familiar and unfamiliar questions, and (iii) systematic biases in the administration of the survey instruments such as sampling errors, role of the interviewer and the reactions of the respondents.

b) Opinions are subjective and may be unstable over time and thus this retards the development of a general theory.

c) It is difficult to capture the opinions of a group of respondents or analyse the dynamics in consensual processes.

B) Empirical Research

As defined in the dictionary, *empirical* refers to "something which originates in or is based on observation or experience". Thus, this approach requires the researcher to observe and/or experience things for himself rather than through the mediation of others. In this method, the researcher must enter the arena of action and either experience the phenomena himself or be an eye-witness to the events that take place. Empirical research methods are usually found in domains such as case studies, field studies and laboratory work.

The main advantages of empirical research are as follows:-

a) It is best suited for analysing actual behaviour, for fact-finding or for seeking reality.

b) With respect to case and field studies, it provides the richest context in which research can take place. As for laboratory investigation, it permits stringent controls to be imposed upon the subject of the study.

c) Sophisticated monitoring equipment or instrument may be employed to obtain accurate and reliable information for analysis.

However, it has a number of drawbacks as follows:-

a) The analysis is limited to the present and it is not possible to analyse events in the past or future.

b) It is time consuming and most of the time, only a few situations may be investigated.

c) In case studies, it is usually difficult to determine the parameters surrounding the problems. As for laboratory investigation, crucial variables may be excluded in an attempt to achieve a clean experiment or the test may suffer from biases due to inherent bias in the design and the conduct of the experiment. Furthermore, the respondents which are subject to the investigation may by influenced by overt or covert hostility toward the researcher or the experiment, thus resulting in unreliable or inaccurate results.

C) Archival Research

This approach is mainly concerned with the examination of recorded facts. As identified by John W. Buckley, Marlene H. Buckley and Hung Fu Chiang (6), there are basically three main domains (data sources) in this method namely: (i) primary, (ii) secondary, and (iii) physical. The differentiation between primary and secondary data is well explained by Murdick (7) who defines a primary archive as one consisting of original documents or official files and records while the secondary sources include publications of data gathered by other researchers. The physical domain consists mainly of ad hoc physical evidence which is often investigated or collected when solving investigative problems.

The main advantages of this method are as follows:-

a) It is able to access and manipulate a vast quantity of data and is suitable for the analysis of data in documents, official files and records, data banks and also information as recorded in the physical environment.

b) It is suitable for historical analysis and the extrapolation of past trends into the future.

c) It is possible to obtain relatively large samples of data to facilitate statistical analysis. Furthermore, more accurate results and generalisations may be made based upon the vast amount of information.

The main limitations of this approach are listed below:-

a) The collection of data suffers from the following deficiencies :-

   i) **Selective depositing** - This occurs when the information presented exhibits systematic bias towards certain matters such as events of historical significance, political or economic systems, or military achievements.

   ii) **Selective suicidal** - This results when the information is incomplete due to the failure to gain access to determine the rationale of those who failed to communicate. For instance, unpublished manuscripts or out of print books may contribute to biases in the collection of information.

   iii) **Selective retrieval** - In this case, the information collected suffers from systematic bias and sampling errors. For example, an investment analyst may place greater emphasis on certain performance indices to persuade his client to invest in particular investment portfolio.

   iv) **"Filling in the gap"** - This occurs when the researcher adds his own suppositions in an attempt to "complete the record".

   v) **Biases inherent in the researcher** - This refers to the personal prejudices (consciously or unconsciously) of the researcher.

b) The problem of communication is more acute as compared to other methods such as Opinion or Empirical research.

D) Analytical Research

This method involves solving problems analytically, that is, by breaking down the problem into its component parts so that its true nature and the causal relationships of its variables may be determined. It depends on the logical power and abilities of the researcher to determine the solutions to the problems and no reference to explicit external data sources is necessary. Analytic research is basically an intellectual research which demands exhaustive study into a problem by the researcher. It requires deep thinking and logically reasoning to determine the cause and effect of a problem.

The main benefits of this approach are as follows:-

a) It is best suited for cerebral activity and provides the most scope for imagination and creativity.
b) It can propose theories which are beyond impressions or reality and does not require additional data. The solution to the problem lies within the researcher.
c) It is most suitable when using (i) logic, (ii) philosophy and (iii) operations research techniques such as mathematical modelling, flowcharting, network analysis, decision strategies, algorithms and heuristic methods.

The main limitations of this method are as follows:-

a) It can be easily abused and may be employed by some researchers to obscure the truth or mislead the unwary.
b) Researchers undertaking this approach often have an unwillingness or inability to adopt or apply scientific methods to the research problem thus making analytic research sloppy.

c) It suffers from methodological pitfalls such as logical errors, problems of semantics, failure to meet epistemological criteria, failure to meet methodological criteria and failure to meet metaphysical criteria.

7.2.1 Choice of research methodology

By comparing the above research methodologies with reference to the requirements of the proposed decision support and risk management system, this researcher has decided to adopt a combination of Archival and Opinion Research approaches for the study. The Archival Research method provides the most accurate and reliable means of collecting, collating and analysing large quantities of tender bid data. As this study is the second phase of a research program currently undertaken by the Building Department of Heriot-Watt University, initial contact had already been established with the Builders' Conference in London for the collection of tender bid data of refurbishment work. A total of 1350 tender bid records (lump sum refurbishment contracts) was collected by Quah (8) during the first phase of the study. These data were collected from a total of 670 refurbishment contractors who are operating in London and span between 1984 and 1987.

In order to set up a decision support system, it is essential that an adequate number of tender bid records (quantitative information) are collected to build up a reliable and stable database so as to facilitate accurate processing of information. As such, it would be most logical to expand the existing database (1350 cases) by collecting more information through the Builders' Conference. Thus, the Archival Research method is the most flexible and versatile approach as it enables the collection of a relatively large sample of data and provides the means by which to access and manipulate the data.

Furthermore, since the data is obtained from an independent source, it is generally free from methodological deficiencies such as selective deficiencies, selective suicidal, selective retrieval, "filling in the gap", and biases from the researcher. The Builders'

Conference in London is a trade association which was established in 1935 by 60 London builders with the aim of reducing the intensity of competition. It achieves this objective by providing a tender reporting service to over 200 of it members through the exchange of tender bid information among contractors. Thus, this organisation provides an invaluable source of information which does not suffer from data limitations (inadequate tender records) and bias (only records of one contractor) commonly encountered and criticised by various researchers such as McCaffer (4) and Fine (9).

As for the risk management system, the Opinion Research approach provides a suitable means for obtaining qualitative information on the subjective risk perception of contractors under various bidding environments. This method is considered to be the most appropriate since the required information is highly subjective and sensitive. To overcome the main deficiencies of this approach, various precautionary actions were taken with respect to data collection and sampling techniques which will be discussed in section 7.3.

7.2.2 Research strategy adopted

In order to facilitate data collection and to ensure that appropriate information is collected, this researcher has adopted a progressive research strategy approach to the study. The research was conducted in various stages as follows:-

a) Preliminary investigation and analysis of tender bid data collected in the first phase of the study (existing database of 1350 tender bids).
b) Presentation of research proposal to those contractors who have participated in the first phase of the study and piloting of survey questionnaire on risk perception of contractors.
c) Interviewing of selected contractors using the Repertory Grid technique and collection of tender bid data through the Builders' Conference.
d) Feedback of findings to contractors.

At the outset of this research, this researcher performed a number of preliminary investigations to determine the feasibility of the proposed decision support and risk management system. Consultations were made with fellow colleagues and researchers within the department of building at Heriot-Watt University so as to formulate the appropriate research strategy for the study. Prior to the research, the bidding performance of 12 refurbishment contractors was investigated using data collected in the first phase of the research program in 1986 (10). This pilot study has provided the initial background and impetus to the development of the proposed decision support and risk management system.

Upon completion of the preliminary investigations, the researcher then proceeded to present a short seminar to a group of 15 refurbishment contractors (mainly directors and estimators) during a conference meeting in London. A brief introduction to the objectives and strategy of the research was made and at the same time, a pilot questionnaire survey was conducted on the 15 contractors. The main purpose of the presentation and the pilot survey was two-fold namely: (i) to obtain further support and co-operation from the contractors and (ii) to test the appropriateness, design and format of the survey questionnaire.

The next stage of data collection consists of soliciting detailed information on the risk perception of the contractors when they are tendering under various bidding situations. Based upon the feedback obtained from the pilot survey, appropriate modifications were made to develop the main survey questionnaire. A total of 100 sets of questionnaires was then sent to a sample of 100 refurbishment contractors who were randomly selected from the population of all refurbishment contractors who are operating in London.

The survey questionnaire was then immediately followed by personal interviews of twenty-two refurbishment contractors conducted by the researcher. These interviews were conducted using the well established Repertory Grid Interview technique which is commonly employed in psychological studies to measure people's perception, as discussed in chapter four. At the same time, tender bid data were also collected from the Builders' Conference in London. Details of an additional 911 refurbishment contracts were obtained to form a total of 2261 cases of tender bid records for the database of the decision support system. Finally, the last stage of the research involved analysing the data in the decision support and risk management system and providing feedback information to the contractors.

7.3 Justification of research instrument and sample size adopted

7.3.1 Selection of research instrument and sample size

As for the 2261 cases of tender bid data, the main research instrument employed was that of direct collection by the researcher from the archive tender bid records of the Builders' Conference. A longitudinal research approach was adopted to collect tender bid data spanning over several years so that accurate and reliable information (statistically representative information) may be produced to describe the bidding characteristics of refurbishment work. Furthermore, the collection of data over a period of time also enables the identification of bidding behaviour (trends) of contractors.

Initial contact was established by the researcher through established working relationship between the building department and the Builders' Conference requesting for support and access to the tender bid data (tender bid records of refurbishment work). This was followed by an informal discussion by the researcher, his supervisor and the chief executive of the Builders' Conference regarding the research objectives and strategy. Upon approval by the chief executive, the researcher then proceeded to make arrangements to collect the tender bid data from the conference office.

All the tender bid information (primary archive) are recorded in standardised tender reporting sheets designed by the Conference. A random sampling method was adopted to collect tender bid data from each year (1984 to 1989). Photocopies of these records were then made so as to facilitate the coding process of these information prior to their input into the computer system.

The main benefits of using the direct data collection approach are as follows:-

a) It provides an expedient way of obtaining large quantities of tender bid information.

b) A unique and reliable source of data had been developed through the Builders' Conference in London.

c) Personal direct data collection ensures that all appropriate information were collected thus increasing the effectiveness and efficiency of the data collection process. However, special care has been taken to avoid bias through selective information retrieval.

As for the collection of qualitative information on risk perception of the contractors (directors and estimators), the survey questionnaire and personal interview techniques were adopted. The main purpose of the survey questionnaire is to obtain general opinions from a large pool of contractors with respect to risk management in competitive bidding for refurbishment work. While the personal interview aims to measure quantitatively the risk attitude of a selected pool of refurbishment contractors during competitive tendering.

The use of a survey questionnaire offers numerous advantages as given below:-

a) It is an effective, efficient and consistent technique for exploring and soliciting information on attitudes, beliefs, values, motives and experience of the selected contractors. This technique also enables the researcher to identify general trends of risk perception, attitudes and strategies of contractors in competitive bidding.

b) It is one of the simplest and most direct ways to obtain qualitative information from a wide population of contractors and also a description of the contractors' behaviour.

c) It is relatively less expensive than other research approaches in collecting information. Furthermore, more specific information may be obtained through well structured questionnaires.

d) The information obtained is standardised and consistent due to the structuring of the survey questions.

e) It allows the contractors adequate time to response to the questions thereby increasing the reliability and accuracy of the responses.

The survey questionnaire was carried out in two main stages as described below:-

a) A pilot survey was conducted using the guidelines as suggested by Sinclair (11). Individual criticisms were invited from fellow research associates, academics and statisticians (Heriot-Watt University) with regard to the design and format of the pilot questionnaire. Appropriate amendments were then made to increase the accuracy and reliability of the questionnaire. After which, the pilot questionnaire was given to a sample of 15 contractors (directors and estimators) during a seminar presentation given by the researcher. Any queries with regard to the questionnaires were answered and clarified by the researcher during the seminar session. This procedure ensures that the respondents understood the exact meaning of the questions in the survey questionnaire. The pilot questionnaires were then fed back to the researchers for further modifications and re-examination. The pilot survey has provided much benefits to the researcher in understanding the suitability of the design and format of the questionnaire, its accuracy and reliability and the likely response rate.

b) The second phase of the research survey consists of the main survey of 100 refurbishment contractors in London. This sample of contractors includes a list of 42 refurbishment contractors who have participated in the first phase of the study undertaken by Quah (8) together with 58 contractors who were randomly selected from the Kelly's business directory (12). As such, this group of contractors may be considered to be a statistically representative sample of all refurbishment contractors in London. A set of questionnaires was then sent to each of the selected contractors with a covering letter stating the purpose of the study. The details of the design and structure of the main survey questionnaire will be discussed later in section 7.3.2.

In determining the risk perception of contractors, a cross-sectional approach has been adopted by the researcher. From the response of the main research survey, twenty-two contractors (7 small, 7 medium and 8 large sized firms) agreed to be interviewed. This group of contractors provides a representative cross-section of all refurbishment contractors in London. As such, the personal interview provides a normative survey to obtain information on the risk attitudes of refurbishment contractors.

In order to measure the risk attitude of contractors and determine the relationships among different risk factors, this researcher has utilised the Repertory Grid Interview technique as discussed earlier in chapter four. The main benefits for adopting this technique in this study may be summarised as follows:-

a) It allows the contractors to increase their awareness of their own risk perception constructs. This serves as useful feedback information which will improve their management of risks in competitive bidding. It also allows contractors to make explicit what is implicit in their thinking processes thereby potentially enhancing the quality of their decisions and judgements.

b) It enables both the researcher and the respondents not only to identify the major dimensions commonly adopted by all contractors in assessing risks, but also to identify the way these constructs are related to one another.

c) The identification of key constructs for assessing risks in competitive bidding may increase the efficiency of the risk management of contractors.

d) This technique also facilitates the comparison of risk perception constructs among different groups of contractors. It explores the degree of agreement or disagreement among contractors in their respective approaches to risk management in competitive tendering.

e) It provides a flexible approach and accurate measurement of subtle perceptions and is easily adaptable.

7.3.2 Design and structure of survey questionnaire

In designing the survey questionnaire, this researcher has followed closely the procedures illustrated by Sinclair (11) as shown in figure 7.2. According to Sinclair, there are five main issues to be considered when designing a survey questionnaire which are described as follows:-

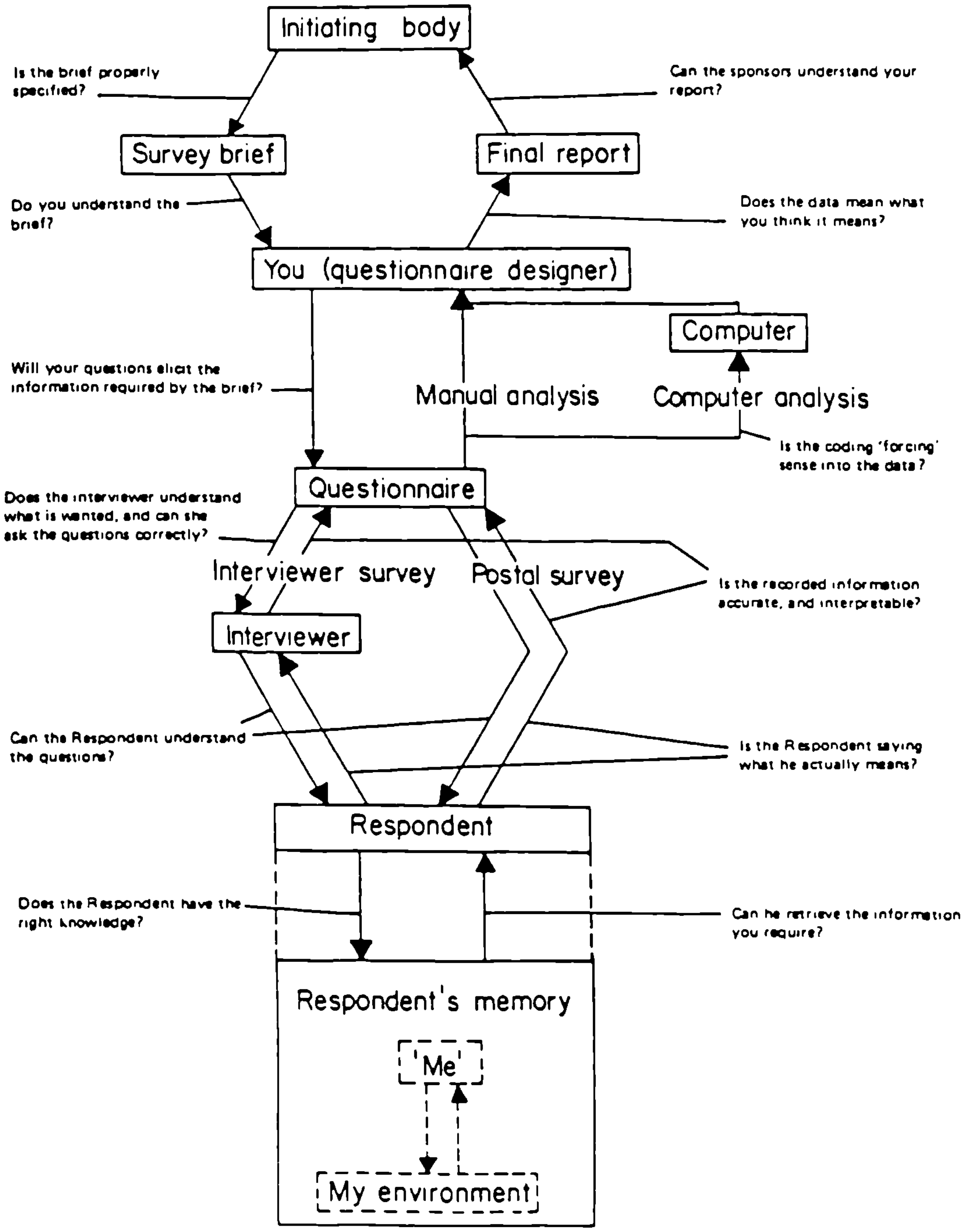
a) Definition of objectives and resources.
b) Coverage.
c) Sampling method.
d) Problems of non-response.
e) Question wording.

The most important step involves the definition of clear and precise objectives of the questionnaire survey. Three important questions were considered at this stage as follows:-

i) What sort of information should be collected ?
ii) What is the level of accuracy required ?
iii) What additional data will be needed to link this survey with other work ?

Figure 7.2 : Procedure for designing survey questionnaire

(Source : M.A. Sinclair, Questionnaire design, Applied Ergonomics, 1975)



Communication problems in survey work, from initial conception to final report.

The arrows may be considered to be processes of communication. The questions indicate some of the problems that might occur. The questionnaire itself affects most of these, and the art of questionnaire design is to minimise the probability of these errors occurring.

From the above considerations, the main objectives of the questionnaire were determined as given below:-

a) To identify pertinent risk factors considered by contractors during tender adjudication.
b) To determine common construction risks encountered by contractors in refurbishment work.
c) To investigate how frequently different risk management strategies are being employed by contractors.
d) To find out whether contractors monitor their bidding performance and identify the main sources of information that are used.
e) To serve as a preliminary investigation prior to the personal interview of the selected contractors.

Since the main data source (tender bid data) is from London (Builders' Conference), it would be most logical and appropriate to survey contractors who are operating in London so that inter-comparison of results is possible between the quantitative data (tender bid records) and the qualitative information (risk perception). As a result, a sample of 100 contractors who are operating in London was selected.

However, the use of mail survey has been severely criticised by many researchers such as Kerlinger (13), Adams and Stacey (14) and Dillman (15). It suffers from major disadvantages such as poor response rate and response bias. There are a variety of techniques suggested by many researchers to overcome these deficiencies. But, from the literature review conducted by Leslie Konuk and Conrad Berenson (16), there is no conclusive evidence supporting the effectiveness of any specific technique in increasing the response rate of mail surveys. However, the use of preliminary notification (17,18,19,20) and followup techniques (19,21) have been widely accepted by many researchers as having significant effects in improving the response rate. Besides this, there are also various techniques which have produced less consistent results in improving response rate such as (a) Questionnaire length, (b) Survey sponsorship, (c) Return envelopes, (d) Postage-Outgoing and return, (e) Personalisation, (f) Covering letter, (g) Anonymity, and (h) Size, production and colour of questionnaire.

Therefore, to ensure a good response rate from the contractors, this researcher has adopted the following techniques as described below:-

a) Preliminary notification was conducted through a seminar presentation (Builders' Conference seminar) by the researcher and also by telephone calls to those selected contractors who did not attend the seminar.

b) The survey questionnaire is divided into three main sections: (i) Section A : *Tender adjudication*, (ii) Section B : *Risk management*, and (iii) Section C : *General information of firm*, and consists of four pages as shown in appendix A.

   Section A primarily seeks to investigate the decision-making processes of contractors during tender adjudication. It aims to identify significant risk factors which affect the pricing decisions of contractors when tendering. From the literature review, a list of risk factors was compiled and each contractor was requested to assign suitable ratings to these factors based upon their respective judgement and experience. The rating of these factors highlights the relative importance of each factor. Besides this, it also enables the comparison of risk perception between individual contractors or between groups of contractors. Furthermore, questions in this section also endeavour to identify the difficulties encountered by refurbishment contractors when pricing for different types of jobs such as industrial, residential and office buildings.

   Section B elicits information on the risk perception of contractors in competitive bidding. It focuses upon the financial risks involved in the pricing of specific items of work in refurbishment projects. This section also attempts to identify the common risk management strategies adopted by contractors.

Section C provides general information on both the respondent and the firm, such as position of respondent, turnover of firm, specialism and experience of firm. It also investigates the main sources of information used by contractors in monitoring their bidding performance and the performance of their respective competitors.

c) A simple tabular design (as shown in appendix A) is adopted so as to facilitate the completion of the questionnaire by the contractors. Each question is tabulated to achieve clarity and simplicity. In order to allow easy coding of the data for computer analysis, an one inch margin is provided on the right hand side of each page of the questionnaire. A 7-point rating scale was adopted for questions involving the rating of factors by the contractors. The main reason for using a 7-point scale is that it allows finer discrimination between the measured factors. This is important especially when the list of variables to be rated is closely associated and the measurement of risk perception is very subtle.

d) A covering letter was enclosed stating the purpose of the research, the researcher and his supervisor and the research strategy. Personalisation of the letter was made by addressing the questionnaire to the director or chief estimator of each firm. The cover letter was signed personally by the researcher's supervisor. A stamped, addressed envelope was also enclosed for the return of the questionnaire.

e) A single followup procedure was performed using telephone calls after launching the main questionnaire survey.

7.3.3 Research strategy and design of Repertory Grid interview.

In an attempt to enhance the understanding of contractors with respect to the risks involved in competitive bidding for refurbishment work, the Repertory Grid Interview technique was adopted to achieve the following objectives as given below:-

a) To elicit personal constructs of key personnel (directors and estimators) of the selected construction firms when they are assessing and evaluating risks in competitive bidding.
b) To identify major constructs adopted by contractors in discriminating between high and low risk bidding situations.
c) To determine key constructs associated with the risk construct of key personnel (directors and estimators) of the selected construction firms.
d) To compare the risk perception constructs of different directors and estimators of the selected construction firms.
e) To provide feedback information to individual contractors (directors and estimators) about their own risk perception.

Prior to interviewing the contractors, this researcher conducted a pilot study on some of his colleagues and associates in order to gain some experience on the "mechanics" of the Repertory Grid Interview technique. This initial test was essential as it enabled the researcher to determine the precise scope of the investigation (interview) and the necessary information required.

Based upon the feedback from the main questionnaire survey, forty-seven contractors responded and twenty-two of them agreed to be interviewed by the researcher. This consists of directors and chief estimators from seven small, seven medium and eight large sized firms. Fifteen of these firms are refurbishment specialists while the remaining seven are general contractors.

A flexible and conversational approach was adopted during the personal interviews. Each interview lasted approximately two hours and a relaxed atmosphere was maintained throughout the interview so as to enable the respondents to express their views and opinions freely. It is vital to employ this approach as the area of investigation is highly sensitive, and normally contractors are unwilling or cautious about sharing knowledge with their respective competitors.

In designing the Repertory Grid Interview, a combination of both provided and free-response elements and constructs was adopted (refer to chapter four). From the response of the survey research, the ten most important adjudication factors (in terms of risk assessment) which are commonly considered by directors and estimators were selected to provide a list of pre-determined constructs for the grid interview. These constructs are printed on standard formatted response forms as shown in appendix A.

As for the selection of elements, tender job sheets (if available) of recently tendered contracts by the selected contractors were obtained through the Builders' Conference. Thus, the list of contracts for each contractor serves as the pre-determined elements (bidding situations) for that contractor during the grid interview. The main rationale for providing the pre-determined elements is two-fold: firstly, to reduce the burden of the respondent trying to recall too many past bidding situations and secondly, the provision of selected elements allows the researcher to choose common bidding situations encountered by different contractors. This provides a common basis for the comparison of risk perception among contractors.

All interviews started with the researcher explaining the overall objectives of the research and the purpose of the repertory grid interview. Thereafter, based upon the availability of job sheets through the Builders' Conference, the respondent (director or estimator) was presented with a list of past contracts (pre-determined elements) for which he has recently tendered. The respondent was then asked to group the provided elements into high or low risk bidding situations. Alternatively, the respondent may have been requested to provide examples of high and low risk bidding situations which he had recently encountered. Using both of these methods (pre-determined and free-response methods), a total of six elements (bidding situations) were elicited comprising three high and three low risk bidding situations.

The elicitation of risk perception constructs from the contractors (directors and estimators) was performed using a mixture of triadic, dyadic and free-response techniques (as explained in chapter four). The choice of method depends on the ease in which the respondent reacts to the construct elicitation process.

In the triadic elicitation procedure, random sets of three elements were displayed and the respondent was asked the following question:-

"Can you tell me something that two of these bidding situations have in common that they do not share with the third bidding situation, in terms of whether you thought they were high or low risk."

Similarly, the dyadic method simply provides two bidding situations at a time to allow the respondents to discriminate the bidding situations in terms of risk. Most of the time, through conversation between the researcher and the respondents, contractors (directors and estimators) tended to respond spontaneously describing why they perceived certain bidding situations as high or low risk. This kind of response is rather instinctive especially when the elements are provided by the respondent himself. Using a combination of the above construct elicitation methods, the process is repeated until adequate constructs have been elicited. Once adequate constructs were obtained, the respondent was then requested to rate the respective elements for each construct. There are basically two approaches to obtain ratings for the grid: namely, a down- method whereby the respondent is asked to assign ratings to various elements after all the constructs have been elicited, and the across-method in which ratings are assigned to all elements immediately after the elicitation of each construct.

In this study, the down-method approach was employed as it enables the respondent to concentrate on each bidding situation at a time. This is necessary as the respondent needed some time to recall details or characteristics of each bidding situation. From the experience of this researcher, the down-method provides a more efficient and expedient way to complete a fully rated grid. Furthermore, this method enables the respondent to concentrate on one bidding situation at a time thereby increasing the reliability of the elicited information (recollection of respondent's memory).

During the process of eliciting constructs, a number of checks were conducted as shown in figure 4.1. This is to ensure that both the labelling of the bi-polar dimensions of each construct reflected the actual meaning intended by the respondent and also that the respondent was satisfied with the assignment of rating to various respective elements.

When the full grid was completed, a simple laddering process was conducted to determine other construct levels of the pre-determined risk construct. This process was performed by asking the following questions:-

a) *"Do you prefer to tender in high risk or low risk bidding situations ?"*

b) *"Why do you prefer high risk bidding situations to low risk situations ?"* (if the answer to question (a) was that the respondent prefers high risk situations).
"Why do you prefer low risk bidding situations to high risk situations ?" (if the answer to question (a) was that the respondent prefers low risk situations).

Besides laddering, the respondent was also asked to state his preferences for the contrasting poles of each construct. For example, the respondent was asked:

"Do you prefer to tender for complex or simple jobs ?"

The interviewing of each director or estimator was completed by asking the respondent to name the most preferred, typical and worst bidding situations out of the six selected elements. The main purpose of this process is to enable the computer program to identify the main constructs which discriminate between the ideal and worst bidding situations.

Thus, in conclusion, this chapter has provided a comprehensive review of various alternative research approaches available and the choice of the most suitable research methodology adopted for this study. The research strategy was formulated logically and progressively to achieve maximum effectiveness and efficiency in accomplishing the objectives of the decision support and risk management system. This has resulted in the use of a combination of various research methods (Opinion and Archival Research) and data collection techniques (Questionnaire survey and Interview). Various precautions and measures were also adopted with respect to sampling techniques in order to increase the reliability and accuracy of the results.

CHAPTER EIGHT

DESCRIPTION OF RESEARCH DATA AND QUANTITATIVE MEASURES ADOPTED

CHAPTER EIGHT

DESCRIPTION OF RESEARCH DATA AND QUANTITATIVE MEASURES ADOPTED

8.1 Introduction

This chapter describes the nature of the research data and its classification and organisation. It explains how the research data were collated and coded to facilitate the development of the decision support and risk management system. Besides this, a brief description of all statistical techniques and quantitative measures which were adopted to analyse the bidding characteristics of refurbishment contracts is provided.

8.2 Description of tender bid data

In order to set up the decision support and risk management system, it is necessary to build two databases namely: (i) tender bid records of contractors and (ii) information on the risk perception of contractors in competitive tendering. The main requisite of the tender bid database is that it should contain adequate information (details of tender bid records and number of cases) to permit accurate processing of the information. The tender bid data should be comprehensive enough so that thorough statistical analysis could be performed to produce reliable and accurate information describing the characteristics of tender bids in refurbishment work. Besides this, the data source should be independent and free from any bias, which is a common criticism made by many researchers.

As discussed in chapter seven, the Builders' Conference in London has been identified as an organisation capable of providing access to the essential data. This organisation which comprises a confederation of contractors mainly operating in the South East of London provides a tender reporting service to a large number of contractors and thus serves as an ideal independent data source.

A total of 2261 refurbishment contract documents were obtained through the Builders' Conference in London. These consist of lump sum contracts with bills of quantities. The data were collected in two stages. The first stage involved the collection of 1350 cases of refurbishment contracts spanning between 1984 and 1987. This set of data was collated and complied by Quah (1) during the first phase of this research program. The second set of data which consists of 911 cases of tender bids (1987 to 1989) was collected by the researcher. Both these sets of data were combined to form the database of tender bid records for the decision support system. This database comprises tender bid records of refurbishment contractors who are mainly operating in London. The tender bid data were recorded on job sheets of the Builders' Conference and contained the following information:-

a) Date of tender.

b) Type of client.

c) Type of project.

d) Project location.

e) Number of bidders.

f) Identity of bidders.

g) Tender bids of bidders.

8.3 Description of survey questionnaire information and Repertory Grid data

The information on risk perception of contractors (directors and estimators) during competitive tendering were obtained by means of survey questionnaire and personal interviews of the contractors. Due to the sensitivity and subjectivity of the data, a well established psychological technique (Repertory Grid interview) was adopted to obtain information on how contractors perceive and assess risks under different bidding situations. The collection of qualitative information on the risk perception of contractors was carried out in two phases. Firstly, a set of survey questionnaires (as shown in appendix A) was mailed to each of the 100 participating contractors. This was then followed by conducting personal interviews on selected contractors (twenty-two in total). The main information obtained through the questionnaire response of forty-seven contractors includes the following :-

a) **Tender adjudication factors** - This contains the rating of various tender adjudication factors in order of their importance in influencing the pricing decisions of management during tendering.

b) **Risk management strategies of contractors** - This consists of information identifying the main sources of risks encountered by contractors when competing for refurbishment contracts. It also highlights the common risk management strategies adopted by contractors. Besides this, it also identifies the common sources of information which contractors used in order to reduce the risks involved in competitive tendering.

c) **General information of company** - This comprises information on the company such as firm size, specialism, experience, turnover, tender success rate, decision-making strategy and designation of respondent.

With respect to the risk perception of contractors, information on the personal risk constructs of individual contractors (directors and estimators) were contained in the repertory grid as shown in table 8.1. The fully rated grid provides information on the types of constructs which enable each individual contractor to discriminate between high or low risk bidding situations. In addition, the rating of each construct also enables the determination of the association between different constructs and the identification of key constructs representing the risk perception of contractors.

Table 8.1 : Example of fully rated grid of one contractor

(a) Pre-determined constructs

Construct		Elements							Construct
		A	B	C	D	E	F		
High accuracy in cost estimate	-	2	6	3	3	2	2	+	Low Accuracy in cost estimate
Good relationship with client	-	7	4	2	2	3	1	+	Poor relationship with client
Good relationship with consultants	-	3	2	2	3	2	1	+	Poor relationship with consultants
Low workload of contractor		NA	NA	NA	NA	NA	NA		High workload of contractor
High credit worthiness of client	-	2	2	1	1	2	1	+	Low credit worthiness of client
Few bidders (3 or 4 bidders)		NA	NA	NA	NA	NA	NA		Many bidders (more than 5 bidders)
Small job size	-	3	6	3	3	2	1	+	Large job size
Low risk	+	4	6	3	2	3	1	-	High risk
Easy location of work	-	2	6	3	4	2	3	+	Difficult location of work
Low complexity	+	2	6	3	1	1	1	-	High complexity
Know identity of bidders		NA	NA	NA	NA	NA	NA		Do not know identity of bidders

(b) Free response constructs

Construct		Elements							Construct
		A	B	C	D	E	F		
Low intensity of work	+	3	5	1	2	6	2	-	High intensity of work
Standard form	+	7	4	2	3	2	2	-	Modified form
Low degree of temporary work	-	6	7	5	4	5	2	+	High degree of temporary work
Little noise protection	-	6	7	4	6	6	6	+	Lots of noise protection
Low LD	-	5	2	4	2	3	3	+	High LD
Vacant building	+	3	2	3	6	7	6	-	Occupied building.
No protection of listed building	-	5	6	4	4	5	6	+	Protection of listed building

(Note: Elements A to F = different projects, rating 1 = low risk , rating 7 = high risk, +/- indicates the positive/negative preferences of contractor, NA = risk constructs which are not adopted by contractor when discriminating between high or low risk bidding situation.)

8.4 Organisation and classification of data

To facilitate computer analysis and the development of the proposed decision support system, it was necessary to code all this tender bid information systematically. The guidelines as laid down in the CI/SfB classification (2) were adopted to classify the information into various categories as shown in table 8.2. The names of firms were also coded so as to maintain anonymity and confidentiality. All tender bid prices were also indexed to 1988 using the BCIS tender indices as shown in appendix B. The coded data were then input into a database (SPSS-X format) in the mainframe computer (DEC VAX 8700) at Heriot-Watt University. For simplicity and easy data editing purpose, the tender bid information was organised and keyed into the database using a fixed data format as displayed in table 9.1.

Table 8.2 : Classification and coding of tender bid data

VARIABLES	CATEGORIES	CODES
Date of tender	1984	2
	1985	3
	1986	4
	1987	5
	1988	6
	1989	7
Job size	Less than £100,000	1
	£100,000 to £250,000	2
	£250,000 to £500,000	3
	£500,000 to £750,000	4
	£750,000 to £1.00 m	5
	£1.00 m to £1.25 m	6
	£1.25 m to £1.50 m	7
	£1.50 m to £1.75 m	8
	£1.75 m to £2.00 m	9
	£2.00 m to £2.25 m	10
	£2.25 m to £2.50 m	11
	£2.50 m to £2.75 m	12
	£2.75 m to £3.00 m	13
	Over £3.00 m	14
Job type	Transport and Utility	1
	Industrial	2
	Administrative, Public and Office	3
	Health and Welfare	4
	Refreshment, Recreation and Entertainment	5
	Religious	6
	Education, information and scientific	7
	Residential	8
Client type	Public	1
	Private	2
Job location	London and outer London	4
	Outside London	5
Number of bidders	Three	3
	Four	4
	Five	5
	Six	6
	Seven	7
	Eight	8
	Nine	9
	Ten	10

As for the repertory grid data, information from the fully rated grid was coded and input into a specially developed computer program (Flexigrid, which will be described in chapter nine) in a micro-computer.

8.5 Description of statistical techniques and quantitative measures adopted

In this study, various statistical tests and quantitative measures were utilised so as to describe the bidding characteristics of refurbishment contracts. These are described briefly as follows:-

8.5.1 Measures of central location

a) **Mean** - The mean (or the "arithmetic mean") provides a measure of central location. It is commonly used for measuring the central tendency of symmetrical distribution and is usually referred to as "the average".

b) **Median** - This is the value of the middle observation of a distribution. It is a more robust measure of central location particularly for non-symmetrical distributions since it is not affected by extreme values.

8.5.2 Measures of dispersion

a) **Range** - This is simply the difference between the highest and the lowest values. In this study, it is used to measure the dispersion of tender bids within a contract. In order to allow comparison of bid dispersion over a wide range of projects (different job sizes), it is necessary to standardise the bid range. The standardised bid range is determined as follows:-

Bid range = (Highest bid - Lowest bid) 100 / Lowest bid

The bid range is highly sensitive to extreme values or outliers (non-genuine or erroneous bids) and thus does not provide a consistent and reliable measure of bid dispersion. However, it has been adopted in this study for the purpose of comparing the results with other researchers.

b) **Interquartile range and bid RD** - The interquartile range is used to measure the difference between the upper and lower quartiles of a tender bid distribution (the bids being arranged in ascending order). It is a relatively more robust measure of bid dispersion and is not affected by extreme values or outliers. The derivation of the interquartile range for different number of bidders in a contract was computed by Korabinski (the researcher's adviser on statistical matters) as shown in appendix C. In order to compare the bid dispersion for different projects (varying job sizes), it is necessary to standardise the interquartile range. This standardised measure is termed "bid RD" and is determined as follows:-

$$\textbf{Bid RD} = (Q3\text{-}Q1)\ 100\ /\ Q2$$

where Q1 = Lower quartile

Q2 = Median quartile

Q3 = Upper quartile

8.5.3 Measures of shape of distribution

a) **Skewness** - This measures describes the shape of a distribution. In this study, it is used to determine the symmetry of tender bid distribution in a contract. A positive skewness indicates that more bids are clustered towards the lowest bid while a negative skewness shows that more bids are located near the highest bid. While a skewness of zero would indicate that tender bids are distributed symmetrically.

b) **Kurtosis** - The kurtosis measures the peakedness of a distribution and also determines how much is in the tails of a distribution. It provides an indication as to how tender bids in a contract are clustered together. A high positive kurtosis indicates that bids are clustered very closely, together while a negative kurtosis would mean that bids are more evenly or uniformly distributed in a contract. While a kurtosis of zero would mean that the peakedness of bids is close to a normal distribution.

8.5.4 Measure of level of competitiveness

a) **Bid spread** - The bid spread measures the margin between the lowest and second lowest bids of each contract. The extent of this margin provides a yardstick for measuring the level of desire (keenness) and bidding efficiency of contractors. According to Park (3), the bid spread is significant for the following reasons:-

i) The bid spread indicates, to some extent, the intensity of competition for a job.

ii) It measures the amount of money left "on the table" and tells how much higher the lowest bidder could have been and still taken the job.

iii) An unusually wide bid spread is probably indicative of an estimating error on the lowest bid especially if the second and higher bids are grouped closely together. However, it may also refer to an extremely keen bid of a contractor.

The bid spread is also standardised as follows:-

Bid spread = (Second lowest bid-Lowest bid) 100 / Lowest bid

8.5.5 Statistical analysis and tests adopted

Various statistical measures and tests were adopted in analysing the data so as to describe the bidding characteristics of refurbishment contracts (lump sum contracts) and the risk perception of contractors. All statistical analyses were performed using two statistical packages namely: SPSS-X (4) and Minitab (5) on the mainframe computer at Heriot-Watt University. A significance level of 5% has been adopted throughout the testing of hypotheses for various statistical tests such as one-way analysis of variance and contingency tables except for the development of bidding model (chapter nine). In module 5, a 1% significance level is used so as to achieve higher precision in the hypothesis testing and also to reduce the mathematical complexities of the model.

a) **One-way analysis of variance** - This test is performed to determine whether several population means are equal. For instance, it is possible to determine whether the population means of bid RD are equal for different numbers of bidders

b) **Scheffe test** - This is basically a range test which is conducted to permit pairwise comparison of means between different pairs of groups. It is commonly adopted as a follow-up procedure when significant difference has been detected among different groups. For example, if the one-way analysis of variance indicates that there is a significant difference between the population means of bid spread for different job types, a Scheffe test will determine the pair(s) of job types which have a significant difference in bid spread at the 5% significance level.

c) **Scatterplot and correlation** - This procedure is used to determine the nature and strength of association between any two bidding variables such as bid RD and job size. The scatterplot provides a visual representation of the relationship between the variables while the strength of linear association is measured using the Pearson Product Moment Correlation Coefficient (r). When a correlation coefficient of 1 or -1 is obtained, it indicates strong positive or negative linear association between the variables respectively. However, if the value of r is close to 0, it shows poor or no linear association between the variables.

d) **Regression analysis** - When significant linear association is detected between two or more variables, it is possible to use regression analysis to quantify this relationship by means of a linear regression equation. In a simple regression analysis, the regression equation consists of one dependent variable (Y) and one independent variable (X). Hence, the dependent variable can be used to explain the variation of the independent variable using the equation. A coefficient of determination (R^2) is computed to determine the goodness-of-fit of the line. Similarly, a multiple regression analysis adopts a number of independent variables to explain the variation of one dependent variable.

e) **Contingency table test** - This is used to test whether the proportions of several populations are equal. For example, it is possible to determine whether high risk and low risk bidding situations are distributed in similar proportions for different job types (office, residential or industrial buildings) at the 5% significance level.

CHAPTER NINE

ANALYSIS OF RESEARCH RESULTS

CHAPTER NINE

ANALYSIS OF RESEARCH RESULTS

9.1 Introduction

This chapter presents the results of the research showing the output of the decision support and risk management system for competitive bidding in refurbishment work. The main findings of the study are presented according to the respective modules of the decision support and risk management system: (i) Module 1 - Databases of tender bid records and Repertory Grid data, (ii) Module 2 - General information of bidding characteristics , (iii) Module 3 - Contractor's analysis, (iv) Module 4 - Competitors' analysis, (v) Module 5 - Bidding models and (iv) Module 6 - Risk management system. The results of the analysis are also compared with past research work on competitive bidding so as to validate and confirm the findings.

9.2 Module 1 - Databases of tender bid records and Repertory Grid data.

The decision support and risk management system has two main databases namely: (i) tender bid records and (ii) Repertory Grid data. The tender bid database comprises 2261 records of lump sum refurbishment contracts in London. Details of each tender bid record is described earlier in chapter eight. The data were input into a database (SPSS-X fixed data format as shown in table 9.1) in the mainframe computer (DEC VAX 8700) at Heriot-Watt University.

The Repertory Grid database consists of the fully rated grid obtained through the interview of twenty-two refurbishment contractors. It contains information on the risk perception constructs of key personnel (directors and estimators) of the selected construction firms. These information are stored in a microcomputer which uses a specially developed software program called Flexigrid (which will be discussed in section 9.7) to analyse the repertory grid data.

Table 9.1 : Database of tender bid data in SPSS-X format

```
+-----------------------------------------------------------------------+
|                                                                       |
|12868 5 03 02 2 8 4 256 120 131 000 000 000 000 000 000 000 00112247   |
|      00120952 00126335 00000000 00000000 00000000 00000000 00000000   |
|      00000000 00000000 07/08/1987                                     |
|12874 5 03 06 2 8 4 288 241 533 000 000 000 000 000 000 000 01189556   |
|      01339953 01363899 00000000 00000000 00000000 00000000 00000000   |
|      00000000 00000000 03/08/1987                                     |
|12875 5 04 02 2 1 5 606 605 607 310 000 000 000 000 000 000 00219973   |
|      00257233 00300641 00320000 00000000 00000000 00000000 00000000   |
|      00000000 00000000 07/08/1987                                     |
|12899 5 06 14 2 8 4 017 030 608 073 021 131 000 000 000 000 05974000   |
|      06295400 06328111 06341782 06350000 07382879 00000000 00000000   |
|      00000000 00000000 11/08/1987                                     |
|12928 5 09 03 1 4 5 020 152 178 196 021 193 410 024 028 000 00346096   |
|      00354469 00366721 00379188 00407200 00415349 00424884 00429148   |
|      00430819 00000000 11/08/1987                                     |
|12945 5 06 06 1 4 4 578 237 061 154 028 310 000 000 000 000 01052491   |
|      01081003 01093243 01303494 01425192 01441089 00000000 00000000   |
|      00000000 00000000 05/08/1987                                     |
|12954 5 03 03 2 8 4 192 021 023 000 000 000 000 000 000 000 00346000   |
|      00388199 00467256 00000000 00000000 00000000 00000000 00000000   |
|      00000000 00000000 03/08/1987                                     |
|12962 5 07 03 2 8 4 609 569 610 175 328 391 240 000 000 000 00452611   |
|      00474375 00493289 00501233 00542196 00612331 00629111 00000000   |
|      00000000 00000000 14/08/1987                                     |
|12975 5 06 03 2 8 4 021 269 158 256 611 015 000 000 000 000 00275076   |
|      00317200 00357837 00373606 00386067 00439368 00000000 00000000   |
|      00000000 00000000 03/08/1987                                     |
|12984 5 04 05 1 3 4 241 350 007 215 000 000 000 000 000 000 00805589   |
|      00883457 00899917 00905668 00000000 00000000 00000000 00000000   |
|      00000000 00000000 05/08/1987                                     |
|                                                                       |
+-----------------------------------------------------------------------+
```

9.3 Module 2 - General information of bidding characteristics

9.3.1 Descriptive statistics of tender bids (Population analysis)

9.3.1.1 General information about refurbishment contracts

a) Number of bidders

Figure 9.1 provides a histogram of tender bids (2261 cases) plotted according to the number of bidders per contract. The number of bidders per contract for refurbishment work ranges between three to ten bidders. The mean number of bidders is 4.80 and has a standard deviation of 1.42. The distribution of contracts for different numbers of bidders is positively skewed, with more contracts having four to five bidders (534 and 580 cases respectively) as shown in figure 9.1.

The mean number of bidders in refurbishment contracts (lump sum contracts) is compared to the results of other researchers such as Quah (1), Park (2), Skitmore (3). As illustrated in table 9.2, the mean number of bidders for refurbishment work is comparatively lower than new-build work. This simply indicates that refurbishment contracts are less competitive in nature and thus prima facie, refurbishment contractors should achieve a higher rate of success in competitive tendering.

b) Job size

The histogram of tender bids by job size in figure 9.2 shows that a large proportion of refurbishment contracts are within the £100,000 to £500,000 value range (52.6% of all contracts). The distribution of bids by job size also reveals that there are not many large refurbishment contracts (over £3 millions) available in the refurbishment market. This is clearly reflected in the small number of jobs (50 out of 2261 cases) as recorded by this relatively large sample of refurbishment contracts over the last 6 years (1984 to 1989).

Figure 9.1 : Histogram of tender bids by number of bidders per contract

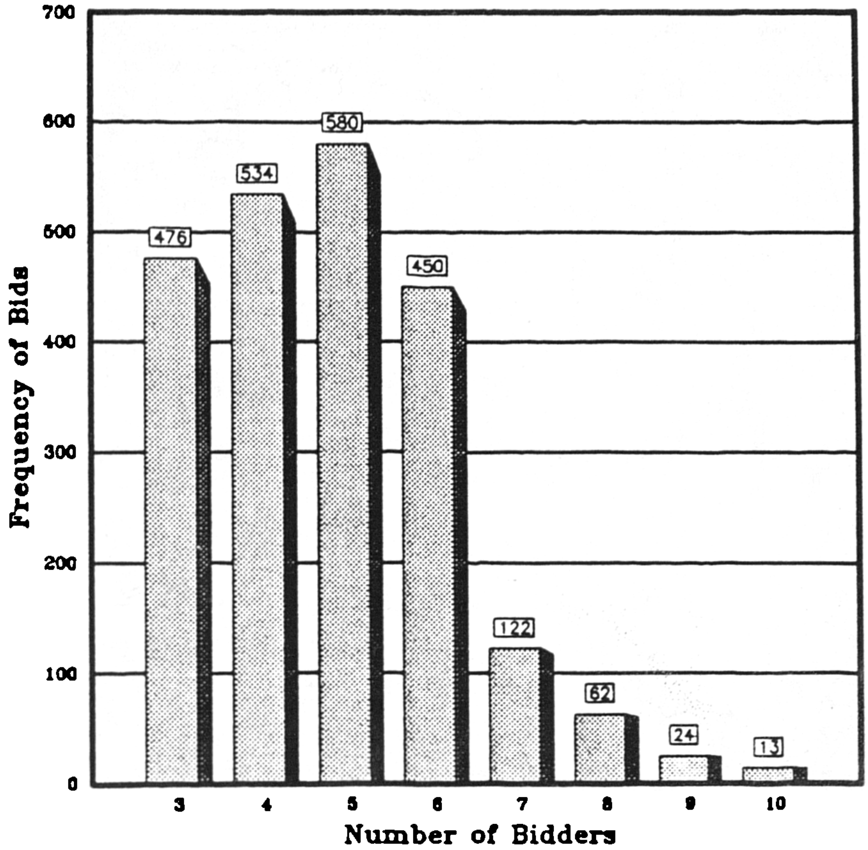
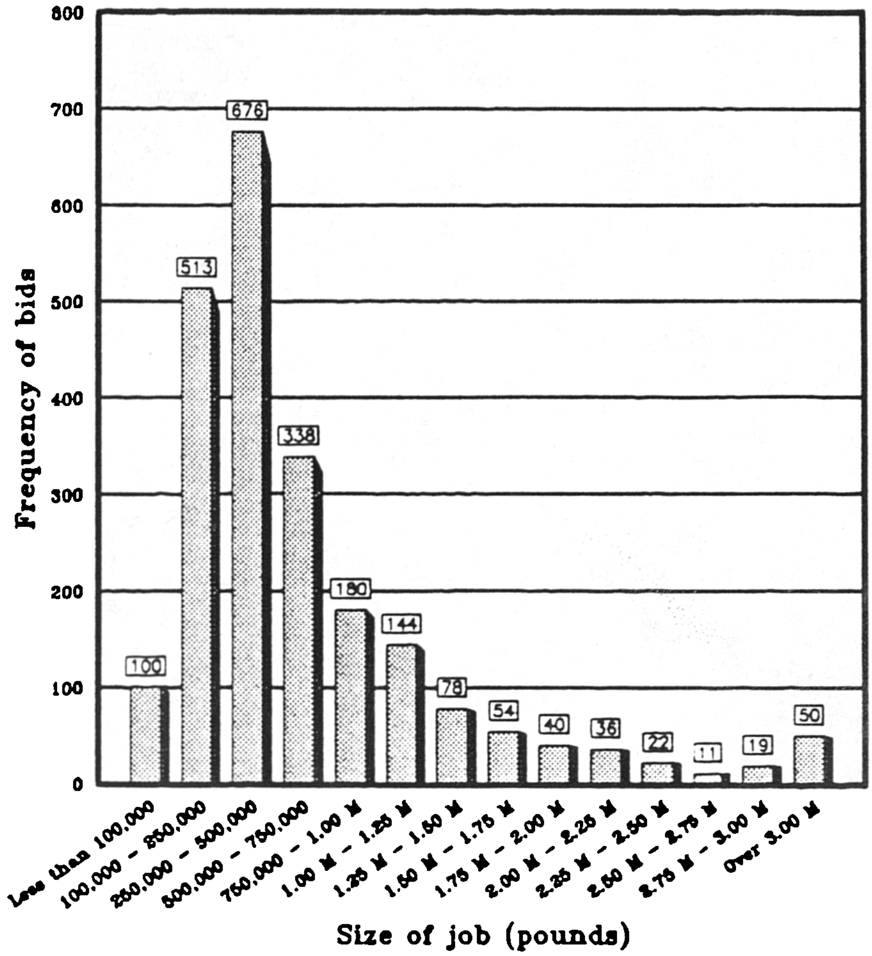


Table 9.2 : Comparison of mean number of bidders among researchers

RESEARCHERS	SAMPLE SIZE	TYPE OF WORK	MEAN NUMBER OF BIDDERS
Park	100	New build	7.00
Skitmore	269	New build	6.10
Quah	1350	Refurbishment	4.80
Teo	2261	Refurbishment	4.80

(Note: There is an overlap between Teo's and Quah's data)

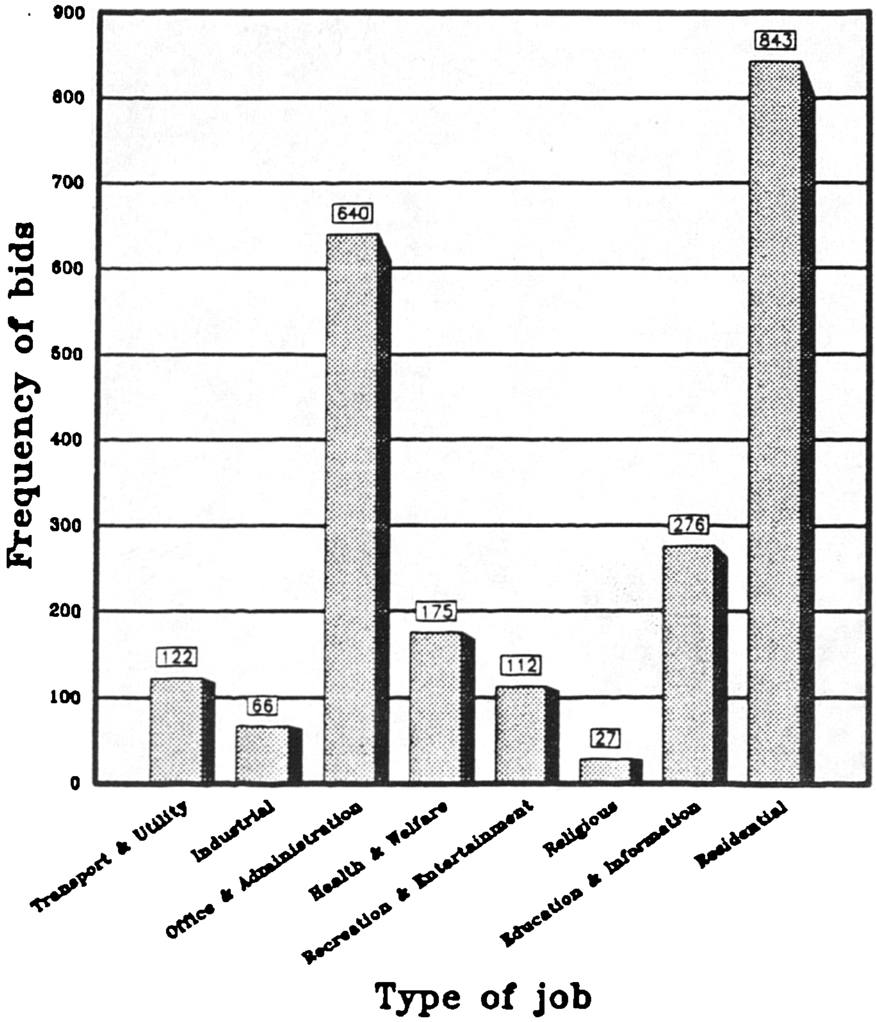
Figure 9.2 : Histogram of tender bids by job size



c) Job type

The refurbishment of office and residential buildings constitutes a large proportion (65.6% of all contracts) of all refurbishment work in the sample as shown in figure 9.3. This is probably attributed to the property boom experienced in London during the last few years (especially in 1987). The increase in construction activities (both new-build and maintenance work) as recorded by the National Economic Development Office (NEDO) is shown in figure 2.1.

Figure 9.3 : Histogram of tender bids by job type



The upsurge in office refurbishment is also partly caused by the impact of technology especially in computer and office automation. The advancements of these technologies have rendered many existing office buildings particularly those built in the '60s and '70s unsuitable for incorporating such new technologies. Coupled with increasing demands of tenants, many owners of commercial properties are compelled to embark on intensive refurbishment programs to enhance the rental value of their properties. As shown in figure 9.3, there is generally less refurbishment work on religious buildings (27 cases). This is probably due to the fact that there are relatively fewer religious buildings as compared to other types of buildings in London.

d) Job location

Figure 9.4 provides a histogram of tender bids arranged according to job location. There are relatively more contracts (72.6% of all contracts) located in London and Greater London as compared to those outside London. This is mainly due to the fact that the sample of tender bids is collected through the Builders' Conference which mainly keeps records for contractors operating in London.

e) Client type

As illustrated by the histogram of tender bids by client type in figure 9.5, there appears to be an equal distribution of jobs between public and private clients. There is a total of 1053 (46.6%) public jobs as compared to 1208 (53.4%) projects from the private sector. The workload from the public sector mainly came from housing associations and public statutory boards while the private sector was the prime motivator of commercial refurbishment in London.

Figure 9.4 : Histogram of tender bids by job location

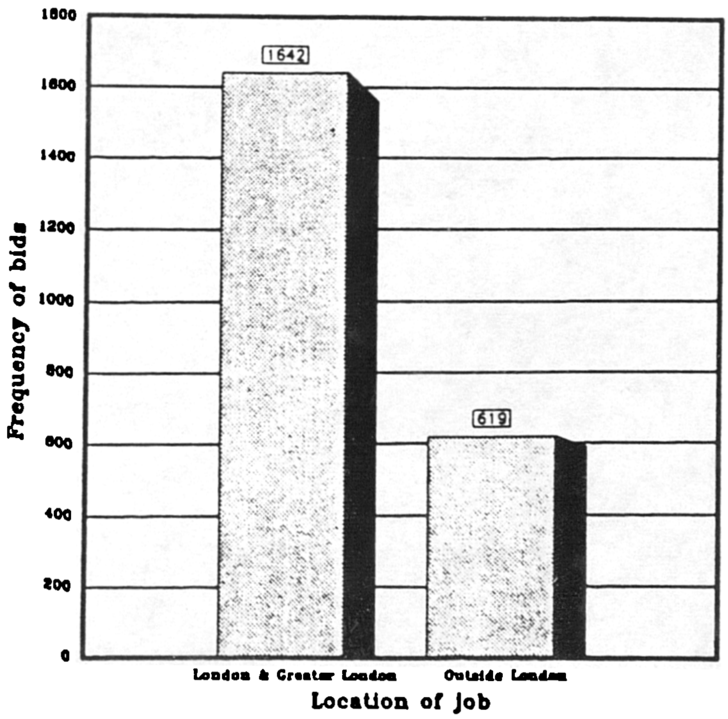
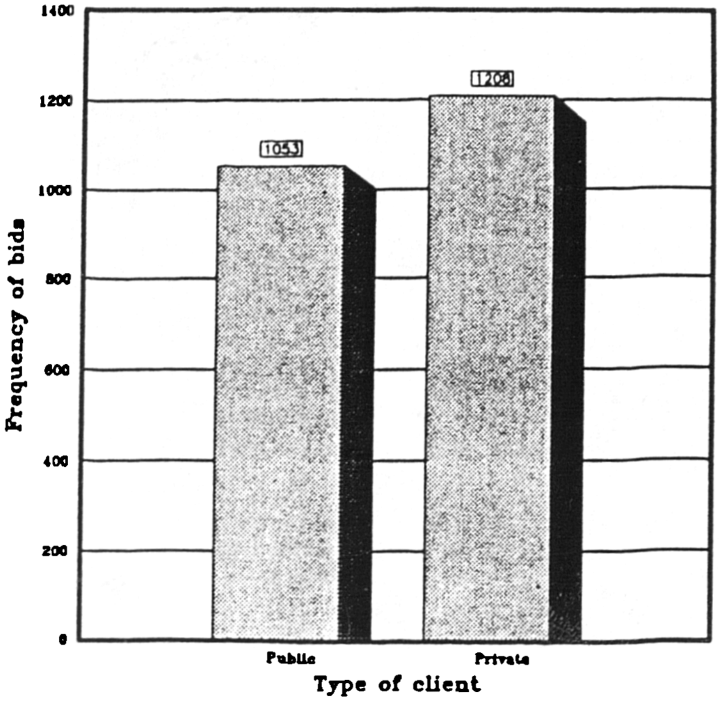


Figure 9.5 : Histogram of tender bids by client type



9.3.1.2 Measures of bid dispersion

a) Bid range

The distribution of the bid range of tender bids is displayed in figure 9.6. The bid range of refurbishment work ranges from a minimum of 1.0% to a maximum of 88.8%. The mean bid range of tender bids is 20.6%. This indicates that the average margin difference between the highest and lowest bid is about 20.6% of the lowest bid. As illustrated in figure 9.6, the distribution of bid range is also positively skewed (skewness = 1.43). The results show that tender bids in refurbishment work vary considerably. This could be attributed to the inherently precarious nature of refurbishment work which generally involves higher uncertainty than new-build work.

Flanagan (4) investigated a total of 129 building projects over 1971 to 1978 and found that the bidding range of tender bids is very wide. The mean bidding range of each year varies between 19% and 26%. A comparison was made between the results obtained by Flanagan and this study as shown in table 9.3. From the table, it is observed that the weighted mean bidding range of refurbishment and new-build work are 20.6% and 21.8% respectively. As suggested by Flanagan (4), the bidding range provides a good guide to assessing the risk perception of contractors. Thus, from the above results it could be inferred that the risk perception of contractors varies considerably for both new-build and refurbishment work.

Figure 9.6 : Distribution of bid range of tender bids

```
BID RANGE

    COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY 10.00 OCCURRENCES

        0        -5
       18         0  ••
      236         5  ••••••••••••••••••••••••
      479        10  ••••••••••••••••••••••••••••••••••••••••••••••••
      428        15  •••••••••••••••••••••••••••••••••••••••••••
      351        20  •••••••••••••••••••••••••••••••••••
      220        25  ••••••••••••••••••••••
      147        30  •••••••••••••••
      127        35  •••••••••••••
       72        40  •••••••
       55        45  ••••••
       63        50  •••••
       21        55  ••
       16        60  ••
       18        65  ••
       11        70  •
        2        75
        4        80
        2        85
        1        90
        0        95
                    I....+....I....+....I....+....I....+....I....+....I
                    0        100       200       300       400       500
                                  HISTOGRAM FREQUENCY

MEAN          20.613    STD ERR        .287    MEDIAN      17.104
MODE           6.655    STD DEV      13.640    VARIANCE   186.048
KURTOSIS       2.341    S E KURT       .103    SKEWNESS     1.426
S E SKEW        .051    RANGE        87.843    MINIMUM       .992
MAXIMUM       88.835    SUM       46604.980

VALID CASES     2261    MISSING CASES     0
```

Table 9.3 : Comparison of bid range of tender bids between new-build and refurbishment work

NEW BUILD WORK				REFURBISHMENT WORK			
YEAR	NO. OF CASES	MEAN BID RANGE%	WEIGHTED MEAN	YEAR	NO. OF CASES	MEAN BID RANGE%	WEIGHTED MEAN
1971	18	26	468	1984	421	19	7999
1972	20	19	380	1985	524	22	11528
1973	13	20	260	1986	250	19	4750
1974	16	22	352	1987	595	22	13090
1975	15	22	330	1988	359	20	7180
1976	17	24	408	1989	112	23	2576
1977	18	19	342				
1978	12	23	276				

Mean weighted bid range for new build work $\frac{2816}{129} = 21.8\%$

Mean weighted bid range for refurbishment work $\frac{47123}{2286} = 20.6\%$

b) Bid RD

The distribution of Bid RD as exhibited in figure 9.7 is also positively skewed. The mean bid RD of tender bids is 11.0% and has a standard deviation of 7.4. As observed in figure 9.7, the value of Bid RD varies from a minimum of 0.4% to a maximum of 62.2%. Thus, the measurement of bid RD provides supporting evidence that tender bids of refurbishment contracts are widely dispersed.

Figure 9.7 : Distribution of bid RD of tender bids

```
BID RD

   COUNT   MIDPOINT   ONE SYMBOL EQUALS APPROXIMATELY 12.00 OCCURRENCES

     91        1   ********
    424        4   ***********************************
    536        7   *********************************************
    377       10   *******************************
    293       13   ************************
    172       16   **************
    131       19   ***********
     90       22   ********
     49       25   ****
     28       28   **
     29       31   **
     20       34   **
      5       37
      7       40   *
      4       43
      2       46
      1       49
      1       52
      0       55
      0       58
      1       61
                   I....+....I....+....I....+....I....+....I....+....I
                   0        120       240       360       480       600
                             HISTOGRAM FREQUENCY


MEAN          10.968     STD ERR        .155     MEDIAN       8.968
MODE           5.259     STD DEV       7.377     VARIANCE    54.422
KURTOSIS       3.631     S E KURT       .103     SKEWNESS     1.582
S E SKEW        .051     RANGE        61.745     MINIMUM       .437
MAXIMUM       62.182     SUM       24797.546

VALID CASES     2261     MISSING CASES     0
```

9.3.1.3 Measure of level of competitiveness

a) Bid spread

As illustrated in figure 9.8, the distribution of bid spread is significantly positively skewed with a mean of 6.2% and standard deviation of 6.8. The value of bid spread varies quite considerably between 0% to 58.1%. The median bid spread is about 4.1%. Thus, the median indicates that 50% of all refurbishment contracts were secured by contractors with 4% of contract value "left on the table".

Figure 9.8 : Distribution of bid spread of tender bids

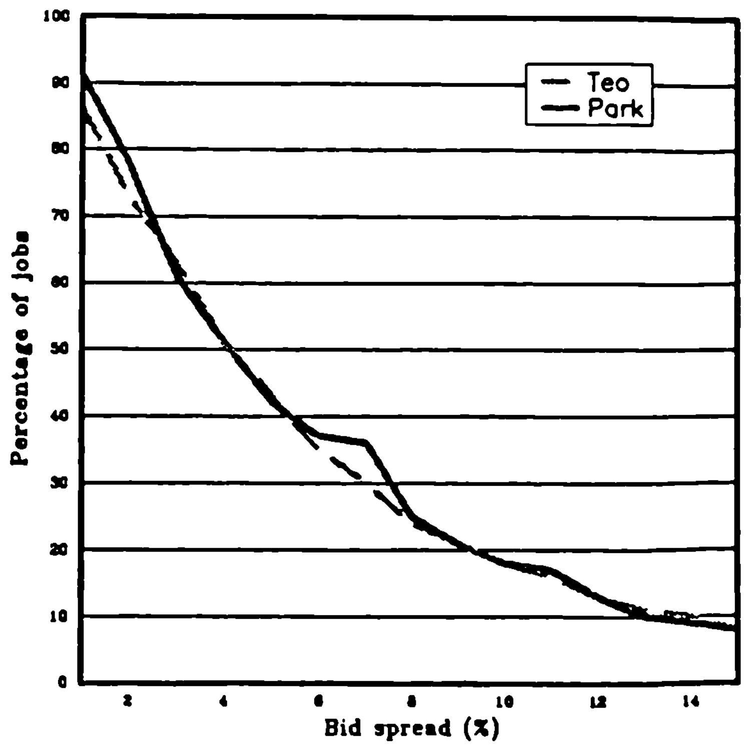
```
BID SPREAD

    COUNT   MIDPOINT   ONE SYMBOL EQUALS APPROXIMATELY 16.00 OCCURRENCES

      173        -1  ***********
      796         2  **************************************************
      567         5  ***********************************
      284         8  ******************
      160        11  **********
      103        14  ******
       49        17  ***
       37        20  **
       30        23  **
       19        26  *
       10        29  *
       10        32  *
        6        35
        6        38
        4        41
        1        44
        0        47
        1        50
        1        53
        3        56
        1        59
                    I....+....I....+....I....+....I....+....I....+....I
                    0         160       320       480       640       800
                              HISTOGRAM FREQUENCY


MEAN           6.203     STD ERR        .144     MEDIAN        4.109
MODE            .000     STD DEV       6.833     VARIANCE     46.684
KURTOSIS      10.872     S E KURT       .103     SKEWNESS      2.716
S E SKEW        .051     RANGE        58.072     MINIMUM        .000
MAXIMUM       58.072     SUM       14026.004

VALID CASES     2261     MISSING CASES     0
```

The results were compared to the findings of Park (2) as illustrated in table 9.4. Park investigated 60 building projects in the United States and found that 50% of the projects have a bid spread greater than or equal to 4%. He also determined the percentage of jobs with a bid spread greater than or equal to any given amount of bid spread as shown in table 9.4. The percentage of jobs with varying bid spread of both Park and this study were plotted as displayed in figure 9.9. It is observed that both the percentage of jobs with bid spread greater than or equal to any given amount are similar between Park's building projects and refurbishment work. This suggests that the proportions of jobs with various bid spread are similar for both refurbishment and new-build work.

Table 9.4 : Comparison of percentage of jobs with bid spread greater than or equal to any given amount between new-build and refurbishment work

PERCENTAGE OF BID SPREAD	PERCENTAGE OF NEW-BUILD WORK (PARK)	PERCENTAGE OF REFURBISHMENT WORK (TEO)
1	91	86
2	78	73
3	61	63
4	51	51
5	42	43
6	37	35
7	36	30
8	25	24
9	21	21
10	18	18
11	17	16
12	13	13
13	10	11
14	9	10
15	8	8

Figure 9.9 : Percentage of jobs with bid spread greater than or equal to any given amount between new-build and refurbishment work



b) Skewness of tender bids

The distribution of the skewness of tender bids in each contract is displayed in figure 9.10. The skewness of tender bids for refurbishment contracts ranges from a minimum of -1.8 to a maximum of 2.2. The mean skewness is 0.1 and thus indicates that tender bids of refurbishment work are approximately symmetrically distributed. Thus, the above result suggests that refurbishment contracts are not very competitive in nature.

Figure 9.10 : Distribution of skewness of tender bids

```
SKEWNESS

    COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY  8.00 OCCURRENCES

        1       -1.8
        5       -1.6 *
       20       -1.4 ***
       24       -1.2 ***
       76       -1.0 **********
      115        -.8 **************
      216        -.6 ***************************
      231        -.4 *****************************
      218        -.2 ***************************
      305         .0 **************************************
      250         .2 *******************************
      238         .4 ******************************
      247         .6 *******************************
      134         .8 *****************
       77        1.0 **********
       68        1.2 *********
       21        1.4 ***
       10        1.6 *
        4        1.8 *
        0        2.0
        1        2.2
                    I....+....I....+....I....+....I....+....I....+....I
                    0         80        160       240       320       400
                                  HISTOGRAM FREQUENCY


MEAN            .051      STD ERR          .013      MEDIAN          .050
MODE           -.381      STD DEV          .608      VARIANCE        .370
KURTOSIS       -.345      S E KURT         .103      SKEWNESS        .017
S E SKEW        .051      RANGE           3.965      MINIMUM       -1.762
MAXIMUM        2.203      SUM           114.360

VALID CASES     2261      MISSING CASES       0
```

c) Kurtosis of tender bids

The distribution of the kurtosis of tender bids is shown in figure 9.11. The mean kurtosis of tender bids is -1.1 and has a standard deviation of 0.6. As illustrated in figure 9.11, the kurtosis of tender bids in refurbishment work ranges from a minimum of -2.9 to a maximum of 3.0. This result shows that the peakedness of tender bids in each contract varies quite considerably in refurbishment work but tender bids are generally more uniformly distributed.

Figure 9.11 : Distribution of kurtosis of tender bids

```
KURTOSIS

    COUNT   MIDPOINT   ONE SYMBOL EQUALS APPROXIMATELY 20.00 OCCURRENCES

        1      -2.9
        0      -2.6
        3      -2.3
       41      -2.0  **
      220      -1.7  ***********
      836      -1.4  ******************************************
      422      -1.1  *********************
      335       -.8  *****************
      164       -.5  ********
      113       -.2  ******
       63        .1  ***
       31        .4  **
       15        .7  *
        8       1.0
        1       1.3
        4       1.6
        2       1.9
        1       2.2
        0       2.5
        0       2.8
        1       3.1
                     I....+....I....+....I....+....I....+....I....+....I
                     0        200       400       600       800      1000
                                   HISTOGRAM FREQUENCY

MEAN          -1.087     STD ERR         .012     MEDIAN      -1.224
MODE          -1.500     STD DEV         .566     VARIANCE      .320
KURTOSIS       3.647     S E KURT        .103     SKEWNESS     1.460
S E SKEW        .051     RANGE          5.840     MINIMUM     -2.865
MAXIMUM        2.984     SUM        -2458.286

VALID CASES     2261     MISSING CASES      0
```

9.3.2 Descriptive statistics of tender bids (Sub-population analysis)

a) Analysis of tender bids by year of tender

The tender bids collected span between 1984 and 1989. In this analysis, the bids were sorted according to their respective year of tender so that various bidding characteristics of the tender bids such as number of bidders, bid RD, bid range and bid spread could be determined for each respective year. The main purpose of this analysis is to determine whether the bidding characteristics of tender bids are affected by the year of tender.

As illustrated in table 9.5, the bidding characteristics of tender bids vary quite considerably between the different years of tender. A One-way analysis of variance test was performed to determine whether the population means of the above bidding characteristics are significantly different for different year of tender. The SPSS-X computer output is shown in appendix D and a summary of the results is compiled in table 9.6.

Table 9.5 : Descriptive statistics of tender bids by year of tender

YEAR OF TENDER	NUMBER OF CASES	MEAN NUMBER OF BIDDERS	MEAN BID RANGE	MEAN BID RD	MEAN BID SPREAD	MEAN SKEWNESS	MEAN KURTOSIS
1984	421	4.57	19.20	10.64	5.83	0.07	-1.11
1985	524	4.83	21.51	11.48	6.06	0.10	-1.07
1986	250	5.15	18.83	9.58	5.41	0.07	-1.02
1987	595	4.73	21.67	11.57	6.56	0.07	-1.10
1988	359	4.81	19.73	10.49	6.57	-0.06	-1.13
1989	112	5.17	22.87	11.25	6.98	-0.01	-1.01

(Note: Bid range, bid RD and bid spread are expressed in percentages.)

Table 9.6 : One-way analysis of variance of bidding characteristics by year of tender

BIDDING CHARACTERISTICS	F-RATIO	F-PROB	ACCEPT OR REJECT NULL HYPOTHESIS
Number of bidders	7.242	0.000	Reject
Bid range	3.860	0.002	Reject
Bid RD	3.571	0.003	Reject
Bid spread	1.801	0.109	Accept
Skewness	3.409	0.005	Reject
Kurtosis	1.900	0.091	Accept

(Note: Null hypothesis is rejected at the 5% significance level)

Table 9.6 shows that the values of F-prob for number of bidders, bid range, bid RD and skewness are extremely small. Thus, we have strong statistical evidence that the population means of number of bidders, bid range, bid RD and skewness are not equal for different year of tender.

The variation in the number of bidders per contract between different years may be attributed to changing market conditions in different years of tender. Generally, the conditions of a market determine the job opportunities available to contractors and thus have undue influence on the level of competition. When there are not many jobs available in the market, more contractors will be competing for the limited number of contracts thereby increasing the number of bidders per contract and vice versa.

In order to determine any significant difference between any two groups of bidding characteristics, a Scheffe test was incorporated into the one-way analysis of variance test. As shown in appendix D, the Scheffe test indicates that the mean number of bidders in

1984 is significantly different from the mean number of bidders in 1986 and 1989 at the 5% significance level. There is also significant difference in the mean number of bidders between 1986 and 1987. Thus, the one-way analysis of variance test provides strong statistical evidence that the mean numbers of bidders varies in different years of tender. In this case, the mean number of bidders are significantly different (at 5% significance level) between 1986 and 1987.

The dispersion of bids (bid range and bid RD) and skewness are also affected by changing level of competition for different years. In a tight market, contractors are more keen to tender for jobs to maintain the workload of their existing resources. As such, bids are more competitive resulting in closer bids (low bid dispersion). On the other hand, when there are many job opportunities in the market, contractors tend to be more selective in tendering and also have wide differences in their expected profit margin. Thus, tender bids are more dispersed in this bidding situation. Furthermore, in a buoyant market, contractors may also receive many invitations to tender at times when they have high workload. Under such circumstances, they may submit non-genuine bids (cover bids) or uncompetitive bids thereby causing tender bids to vary considerably.

Although the Scheffe test shows no significant difference between any two pairs of bid range for different years (appendix D), the bid RD of 1986 is significantly different from that of 1985 and 1987 at the 5% significance level. The Scheffe test also indicates that bid skewness of 1985 (0.10) is significantly different from that of 1988 (-0.06).

The relationship between skewness and year of tender is also acknowledged by Skitmore (3) in his study of 269 new-build projects. Skitmore observed that the skewness of tender bids varies between different year of tender and acknowledged that skewness of bid appears to be correlated to the economic conditions of each respective year. From the above results, we confirm that bid skewness for both new-build and refurbishment work is influenced by the year of tender.

As illustrated in table 9.6, the one-way analysis of variance test shows that bid kurtosis and bid spread are approximately equal for different year of tender. This implies that the mean bid spread and kurtosis of tender bids in refurbishment work are approximately 6% (figure 9.8) and -1.1 (figure 9.11) respectively.

b) Analysis of tender bids by job type

The main purpose of this analysis is to determine the bidding characteristics of bids for different job types in refurbishment work. Tender bids are grouped into various categories of job types and descriptive statistics of the tender bids are determined as shown in table 9.7. The results of the one-way analysis of variance tests as displayed in table 9.8 show that the population means of number of bidders, bid range, bid RD, bid spread and kurtosis are significantly different for various categories of job types (as indicated by the small F-prob values). Thus, we have strong statistical evidence that the above bidding characteristics of tender bids are different for various types of jobs such as office, residential or industrial buildings.

As illustrated in column 3 of table 9.7, the mean number of bidders varies between 4.67 (religious buildings) to 5.12 (education, scientific and information buildings). One plausible reason for this variation could be due to the influence of job characteristics, speciality of contractors or client requirements. Generally, more complex jobs such as religious, health and some residential buildings attract less bidders as not many refurbishment contractors possess the necessary specialist skills and resources to undertake such work. Hence, there are relatively fewer contractors competing in such contracts. Conversely, simple refurbishment contracts such as industrial, educational and office buildings are often competed for by more contractors.

Table 9.7 shows that the mean number of bidders for education, scientific and information buildings is relatively high (5.12) as compared to other types of buildings. This is probably due to the tendering policies of government organisations which often require a

Table 9.7 : Descriptive statistics of tender bids by job type

TYPE OF JOB	NUMBER OF CASES	MEAN NUMBER OF BIDDERS	MEAN BID RANGE	MEAN BID RD	MEAN BID SPREAD	MEAN SKEWNESS	MEAN KURTOSIS
Transport and Utility	122	4.82	21.11	10.71	6.15	0.13	-1.15
Industrial	66	4.85	17.12	9.29	5.64	0.07	-1.13
Office and Administration	640	4.73	18.16	9.71	5.50	0.07	-1.10
Health and Welfare	175	4.95	20.00	11.01	6.04	0.00	-1.13
Recreation and Entertainment	112	4.75	18.77	9.96	5.62	0.18	-1.09
Religious	27	4.67	21.34	10.98	6.35	0.21	-0.95
Education and Information	276	5.12	18.31	9.38	5.45	0.24	-0.98
Residential	843	4.73	23.78	12.74	7.14	0.24	-1.10

(Note: Bid range, bid RD and bid spread are expressed in percentages.)

Table 9.8 : One-way analysis of variance of bidding characteristics by job type

BIDDING CHARACTERISTICS	F-RATIO	F-PROB	ACCEPT OR REJECT NULL HYPOTHESIS
Number of bidders	2.865	0.006	Reject
Bid range	11.947	0.000	Reject
Bid RD	12.678	0.000	Reject
Bid spread	3.969	0.000	Reject
Skewness	1.881	0.069	Accept
Kurtosis	2.148	0.009	Reject

(Note: Null hypothesis is rejected at the 5% significance level)

minimum number of bidders to tender for their contracts. This observation is further confirmed by the Scheffe test as illustrated in appendix D. The test shows that the mean number of bidders for education, scientific and information buildings are significantly different from office and residential buildings at the 5% significance level. Thus, the above results clearly show that the mean number of bidders (level of competition) varies between different types of jobs in refurbishment work.

The dispersion of bids (bid range and bid RD) also varies quite considerably between different job types as shown in table 9.7. The difference in bid dispersion between job types may be attributed to the nature and complexity of various types of jobs. For instance, refurbishment contracts for industrial buildings are often quite simple and do not pose many construction problems such as access restrictions to contractors. As such, contractors are able to estimate the cost of construction more accurately thereby resulting in less disparity of bids. This is clearly reflected in the low bid dispersion of tender bids for industrial buildings (bid range = 17.1% and bid RD = 9.3%) as shown in table 9.7.

On the contrary, tender bids are more widely dispersed in residential buildings as indicated by the high mean bid range of 23.8% and bid RD of 12.7%. This could be attributed to the high level of risks involved in the refurbishment of such buildings. This is particularly so if the work involves high quality residential buildings located in highly sensitive city areas with tenants in occupation. Under such circumstances, contractors often encounter many difficulties in pricing. Furthermore, the assessment of risk also differs considerably among contractors thus causing wide variations in bids.

Another possible reason for the high dispersion of bids in residential buildings could be due to the mix of competition among contractors. The nature and complexity of residential buildings vary quite considerably, ranging from very simple and straightforward kitchen renovation to highly complex re-roofing or restoration work. As explained earlier, the complexity of a project affects bid dispersion due to different risk assessment and pricing approaches of contractors. Thus, tender bids are more widely dispersed in high complexity jobs. Although it would seem logically that simple residential buildings should have lower dispersion of bids due to more accurate pricing by contractors, this is not the case in refurbishment work. The main reason is that such contracts often attract many contractors with varying capabilities and capacities. These contractors have different costs of production (particularly between large and small sized firms) and tendering policies thereby resulting in high dispersion of bids.

The difference in bid dispersion between specific pairs of job types as determined by the Scheffe test indicates that bid range and bid RD of residential buildings are significantly different from those in industrial, office, education, scientific and information buildings at the 5% significance level (appendix D). Thus, the results indicate that dispersion of tender bids is relatively higher in residential buildings than other types of buildings.

Table 9.7 also shows that transport and utility, health and welfare, religious and residential buildings have comparatively higher bid dispersion than other types of buildings. This indicates that such buildings are either more complex in nature or they attract a more heterogeneous mix of contractors in competition. The job characteristics and mix of competition may also affect the variation of bid spread between different job types. As illustrated in table 9.7, residential buildings have much higher bid RD (23.8%) than other types of buildings. This result confirms that the refurbishment of residential buildings involves either more uncertainties or usually tend to attract a more heterogeneous mix of contractors.

As shown in table 9.8, the F-prob value for the one-way analysis of variance test of skewness for different job types is approximately 0.069. This indicates that the population means of skewness for different categories of job types cannot be considered as different at the 5% significance level. Thus, we have no statistical evidence that bid skewness is affected by the type of job in refurbishment work. On the other hand, the kurtosis of bids shows significant difference between various job types as indicated by its small F-prob value (0.036). Therefore, we conclude that the kurtosis of bids (peakedness) is different for various types of jobs at the 5% significance level.

c) Analysis of tender bids by job size

As shown in table 9.9, there are generally more bidders tendering for larger projects (over £3m) than smaller contracts in refurbishment work. The one-way analysis of variance test also shows that the population means of number of bidders for different job sizes are not equal as illustrated in table 9.10. The above results clearly show that the level of competition (number of bidders in competition) is different for various job sizes in refurbishment work. The increasing trend of bidders for larger refurbishment contracts may be attributed to the fact that most refurbishment contracts are small (as shown in figure 9.2) as compared to new-build projects. Therefore, more contractors are eligible to undertake a wider range of contracts (different job sizes). Furthermore, most large sized firms are relatively more keen to tender for large refurbishment projects to achieve their targeted turnover. As illustrated in figure 9.2, there are not many large job opportunities in the refurbishment market. Thus, with limited large contract opportunities in the market, contractors are even more keen to tender for large contracts thereby increasing the number of bidders in competition.

The influence of job size on the number of bidders in competition is also acknowledged by Park (2). He argued that the mean number of bidders in a job will depend upon both the job characteristics and the general competitive situation within the industry. According to Park, logically larger jobs offer greater profit opportunity and should therefore attract more bidders than small jobs. However, as the size of job increases, the number of contractors qualified for the work is likely to decrease (larger commitment of resources). He investigated a total of 100 jobs ranging from US$10,000 to US$70 millions and found that the average mean number of bidders varied with job size as shown in table 9.11. The comparison of the results obtained by Park and this study (as shown in table 9.11) shows that both new-build and refurbishment work exhibit very similar trend. In Park's case, the mean number of bidders increases for jobs over US$100,000 up to US$10m and

Table 9.9 : Descriptive statistics of tender bids by job size

SIZE OF JOB	NUMBER OF CASES	MEAN NUMBER OF BIDDERS	MEAN BID RANGE	MEAN BID RD	MEAN BID SPREAD	MEAN SKEWNESS	MEAN KURTOSIS
1	100	4.03	30.36	17.07	9.46	0.09	-1.24
2	513	4.22	24.83	13.69	8.52	0.48	-1.23
3	676	4.64	20.38	11.07	6.30	0.02	-1.13
4	338	5.07	18.81	9.55	5.19	0.04	-1.03
5	180	5.09	17.61	9.22	4.36	0.11	-1.03
6	144	5.32	18.07	9.27	4.02	0.13	-0.96
7	78	5.67	18.94	8.37	5.63	0.06	-0.73
8	54	5.57	15.73	7.91	4.46	-0.01	-1.04
9	40	5.55	13.24	5.93	3.91	-0.07	-0.78
10	36	5.19	16.46	9.12	3.46	0.13	-1.05
11	22	5.95	17.64	8.69	5.18	-0.26	-0.84
12	11	6.18	14.44	6.38	3.29	0.22	-0.57
13	19	5.53	14.47	7.84	3.55	0.05	-1.14
14	50	6.04	13.04	6.09	3.16	0.13	-0.83

(Note: Bid range, bid RD and bid spread are expressed in percentages.)

(Please refer to table 8.2, page 139, for classification of job size)

Table 9.10 : One-way analysis of variance of bidding characteristics by job size

BIDDING CHARACTERISTICS	F-RATIO	F-PROB	ACCEPT OR REJECT NULL HYPOTHESIS
Number of bidders	25.521	0.000	Reject
Bid range	13.678	0.000	Reject
Bid RD	20.551	0.000	Reject
Bid spread	12.005	0.000	Reject
Skewness	0.830	0.629	Accept
Kurtosis	9.888	0.000	Reject

(Note: Null hypothesis is rejected at the 5% significance level)

thereafter the number of bidders decreases. Similarly, the mean number of bidders also increases for refurbishment contracts up to £1.50m. After which, the mean number of bidders fluctuates randomly between 5 and 6 bidders.

The importance of such analysis is also emphasised by Park. He acknowledged that by relating the number of bidders to job size, useful information may be obtained to assist contractors in formulating more efficient and appropriate bidding strategies. This is particularly so in situations in which the exact number and identity of competitors is not known. Thus, by anticipating the approximate contract value and the likely type of competition to be encountered, contractors may reject invitations to tender without incurring any tendering costs. Indirectly, great savings could be made through the reduction of abortive tendering costs. That is, the above analysis enables contractors to be more selective in tendering and thus increases their chance of success and efficiency in competitive bidding.

From the results of the one-way analysis of variance tests as shown in table 9.10, the population means of bid range, bid RD, bid spread, and kurtosis are also significantly different for various categories of job sizes. Thus, we have strong statistical evidence that the above bidding characteristics of tender bids are influenced by the size of project in refurbishment work.

As observed in table 9.9, there is a general decrease in bid range, bid RD and bid spread as job size increases. This is probably due to the comparability of mix of competition in large job sizes. As the job size increases, the number of contractors who are qualified to undertake such work decreases. Furthermore, competition among these contractors is more comparable thus resulting in lower bid dispersion and bid spread.

Table 9.11 : Comparison of mean number of bidders between new-build and refurbishment work

NEW-BUILD WORK (PARK)		REFURBISHMENT WORK (TEO)	
SIZE OF JOB (US DOLLARS)	MEAN NUMBER OF BIDDERS	SIZE OF JOB (POUNDS)	MEAN NUMBER OF BIDDERS
Less than 50,000	4.8	Less than 100,000	4.03
50,000 - 100,000	7.1	100,000 - 250,000	4.22
100,000 - 500,000	5.5	250,000 - 500,000	4.64
500,000 - 1.00 M	7.3	500,000 - 750,000	5.07
1.00 M - 5.00 M	8.3	750,000 - 1.00 M	5.09
5.00 M - 10.00 M	9.2	1.00 M - 1.25 M	5.32
Over 10.00 M	7.9	1.25 M - 1.50 M	5.67
		1.50 M - 1.75 M	5.57
		1.75 M - 2.00 M	5.55
		2.00 M - 2.25 M	5.19
		2.25 M - 2.50 M	5.95
		2.50 M - 2.75 M	6.18
		2.75 M - 3.00 M	5.53
		Over 3.00 M	6.04

d) Analysis of tender bids by client type

The descriptive statistics of tender bids between public and private clients is displayed in table 9.12. As illustrated in table 9.13, the F-prob values of bid range, bid RD, skewness and kurtosis are substantially greater than 0.05 (5% significance level). Thus, we have no statistical evidence that the population means of bid range, bid RD, skewness and kurtosis of bids are affected by the type of client in refurbishment work. On the other hand, the one-way analysis of variance test shows that the population means of number of bidders and bid spread are not the same for different client type. The F-prob values for number of bidders and bid spread obtained are 0 and 0.01 respectively. Thus, we have strong statistical evidence that the population means of number of bidders and bid spread are not equal for public and private jobs.

Table 9.12 : Descriptive statistics of tender bids by client type

CLIENT TYPE	NUMBER OF CASES	MEAN NUMBER OF BIDDERS	MEAN BID RANGE	MEAN BID RD	MEAN BID SPREAD	MEAN SKEWNESS	MEAN KURTOSIS
Public	1053	5.01	20.46	10.85	5.77	0.07	-1.07
Private	1208	4.62	20.75	11.07	6.58	0.04	-1.10

(Note: Bid range, bid RD and bid spread are expressed in percentages.)

There are generally more bidders in competition for public jobs (mean number of bidders = 5.0) as compared to private contracts (mean = 4.6) as shown in table 9.12. This is probably due to the tendering policies of public clients (statutory boards and district councils). Very often , a minimum number of bidders must be invited to tender for public jobs due to reason of public accountability (obtaining the most competitive quote).

e) Analysis of tender bids by Job location

From the descriptive statistics as shown in table 9.14, there are large variations in the bidding characteristics of bids between contracts in London and those outside London. These variations are confirmed by the results of the one-way analysis of variance as displayed in table 9.15. The population means of number of bidders, bid range, bid RD, bid spread and kurtosis are significantly different between London and outside London.

Table 9.13 : One-way analysis of variance of bidding characteristics by client type

BIDDING CHARACTERISTICS	F-RATIO	F-PROB	ACCEPT OR REJECT NULL HYPOTHESIS
Number of bidders	43.582	0.000	Reject
Bid range	0.246	0.620	Accept
Bid RD	0.493	0.483	Accept
Bid spread	8.043	0.005	Reject
Skewness	1.359	0.244	Accept
Kurtosis	0.978	0.323	Accept

(Note: Null hypothesis is rejected at the 5% significance level)

Table 9.14 : Descriptive statistics of tender bids by job location

JOB LOCATION	NUMBER OF CASES	MEAN NUMBER OF BIDDERS	MEAN BID RANGE	MEAN BID RD	MEAN BID SPREAD	MEAN SKEWNESS	MEAN KURTOSIS
London and Greater London	1642	4.70	21.17	11.41	6.41	0.05	-1.11
Outside London	619	5.07	19.14	9.81	5.65	0.55	-1.04

(Note: Bid range, bid RD and bid spread are expressed in percentages.)

Table 9.15 : One-way analysis of variance of bidding characteristics by job location

BIDDING CHARACTERISTICS	F-RATIO	F-PROB	ACCEPT OR REJECT NULL HYPOTHESIS
Number of bidders	30.373	0.000	Reject
Bid range	10.026	0.002	Reject
Bid RD	21.346	0.000	Reject
Bid spread	5.646	0.018	Reject
Skewness	0.054	0.816	Accept
Kurtosis	6.821	0.009	Reject

(Note: Null hypothesis is rejected at the 5% significance level)

One possible reason for this variation could be attributed to the relatively large pool of contractors with varying capabilities and capacities operating in London. As explained before, the mix of competition has undue influence on the characteristics of tender bids. Conversely, there is normally a smaller group of local builders with more comparable abilities competing for contracts outside London, particularly in smaller towns. These contractors have comparatively fewer differences in their methods and costs of production. Thus, their tender bids tend to be much closer.

The one-way analysis of variance test also indicates there is no statistical evidence of difference in the skewness of bids between London and outside London as shown in table 9.15. But, the kurtosis of bids is different for different job location as indicated by the small F-prob value (0.01).

f) Analysis of tender bids by number of bidders

As shown in table 9.16, the bidding characteristics of tender bids differ quite considerably between different numbers of bidders. The one-way analysis of variance tests confirm that the population means of bid range, bid RD, bid spread and kurtosis are significantly different for various bidding sets (number of bidders). Table 9.17 shows that except for bid skewness, the one-way analysis of variance for bid range, bid RD, bid spread and kurtosis have extremely small F-prob values. This provides very strong statistical evidence that the population means of bid range, bid RD, bid spread and kurtosis are significantly different for different number of bidders.

It is observed from table 9.9, that the dispersion of tender bids (bid range and bid RD) and bid spread are generally smaller for larger contracts. It also shows that there are more contractors in competition in the larger job range. Similar trends are also observed in the characteristics of tender bids as the number of bidders increases (table 9.16). As explained earlier, only large contractors have the necessary resources to undertake large refurbishment contracts. Thus, the above results imply that there are more large contractors in competition for larger contracts in the refurbishment industry. Therefore, there is a more comparable mix of contractors (of similar capacities and capabilities) in competition. These contractors are often more systematic and efficient in their pricing and have quite similar overheads. As a result, their tender bids are usually much closer thereby resulting in lower bid dispersion. The comparability of competition among contractors for larger job sizes is also reflected in the low bid spread for higher bidding sets (more bidders) as shown in table 9.16. Thus, the above results show that bid range, bid RD and bid spread decrease with increasing number of bidders in refurbishment work.

The relationship between bid spread and number of bidders is also investigated by Park (2). Using a sample of 60 projects ranging from US$23,000 to US$123m, he observed that the average bid spread decreases as the number of bidders per contract increases. A comparison between Park's results and this research is tabulated in table 9.18.

Table 9.16 : Descriptive statistics of tender bids by number of bidders

NUMBER OF BIDDERS	NUMBER OF CASES	MEAN BID RANGE	MEAN BID RD	MEAN BID SPREAD	MEAN SKEWNESS	MEAN KURTOSIS
3	476	18.46	12.21	8.91	0.02	-1.50
4	534	20.21	11.81	6.39	0.03	-1.23
5	580	21.99	10.83	5.76	0.08	-0.94
6	450	21.21	9.73	4.86	0.05	-0.86
7	122	20.61	9.43	3.78	0.10	-0.77
8	62	23.54	9.42	4.35	0.06	-0.64
9	24	19.68	8.64	3.10	0.03	-0.73
10	13	17.77	5.76	3.30	0.09	-0.13

(Note: Bid range, bid RD and bid spread are expressed in percentages.)

Table 9.17 : One-way analysis of variance of bidding characteristics by number of bidders

BIDDING CHARACTERISTICS	F-RATIO	F-PROB	ACCEPT OR REJECT NULL HYPOTHESIS
Bid range	3.217	0.002	Reject
Bid RD	7.329	0.000	Reject
Bid spread	18.385	0.000	Reject
Skewness	0.523	0.818	Accept
Kurtosis	97.190	0.000	Reject

(Note: Null hypothesis is rejected at the 5% significance level)

From table 9.18, it is observed that bid spread in refurbishment work is relatively lower as compared to those projects investigated by Park. However, both results indicate that bid spread decreases as the number of bidders increases. This clearly shows that when there are more bidders in competition, jobs tend to be secured with lower bid spread. Using bid spread as a yardstick for measuring bidding efficiency, this finding suggests that contracts are more efficiently secured with more bidders.

Table 9.18 : Comparison of mean bid spread for different number of bidders between new-build and refurbishment work

NUMBER OF BIDDERS	MEAN BID SPREAD (%)	
	PARK (New-build work)	TEO (Refurbishment work)
4 to 6	8.00	5.70
7 to 9	5.80	3.87
10 to 12	3.80	3.30
13 to 15	2.00	*

(Note : * denotes that no information is available as there are no refurbishment contracts with more than 10 bidders in the sample.)

9.3.3 Competitive pattern of tender bids

In this analysis, tender bids are cross-tabulated as defined by selected bidding variables such as bid RD, bid spread and job characteristics (year of tender, number of bidders, job size, job type, client type and job location) so that general trends of bids could be identified. The cross-tabulation of tender bids provides a clear visual representation of bidding patterns for various defined bidding situations as described below:-

a) Number of bidders by job size

As discussed earlier, tables 9.9 and 9.10 analyse the mean number of bidders for different job sizes and determine whether the population means of number of bidders per contract varies with the size of job or not respectively. In this cross-tabulation analysis, we are analysing the distribution of bids for different bidding sets (number of bidders per contract) under various job size categories. As shown in table 9.19, there are 4 main clusters of bids observed in three distinct ranges of job sizes. Jobs of less than £250,000 tend to attract three to four bidders as indicated by the large proportion of bids in this category. A large proportion of contracts (between 60% to 70%) which are less than £250,000 have three to four bidders in competition. This clearly indicates that refurbishment contracts in job size categories 1 and 2 (as shown in table 9.19) are less competitive in nature.

As project size increases, there is a gradual increase in the number of bidders in competition. This is illustrated by the large concentration of contracts (between £250,000 to £750,000) with four to six bidders.

Contracts ranging from £250,000 to £1.75m tend to attract more bidders. This is probably due to the large number of contractors who are eligible and keen to tender for contracts in this value range. Furthermore, a large proportion of refurbishment contracts falls within these job size categories as shown in figure 9.2. Small refurbishment contracts (less than £250,000) normally do not interest larger contractors particularly large firms and refurbishment specialists. As such, these jobs are usually undertaken by small jobbing builders or small sized firms. On the other extreme, large refurbishment contracts are often very complex and require the heavy commitment of resources. Only a limited number of refurbishment contractors are competent to undertake such contracts. Thus, there are relatively fewer bidders (usually five to six bidders) in competition as compared to medium sized contracts. This pattern is clearly reflected in the high percentage of medium sized contracts with more than 6 bidders as shown in table 9.19.

Table 9.19 : Cross-tabulation of tender bids by number of bidders and job size

JOBSIZE size of job by NOBID number of bidders

NOBID — Page 1 of 2

Count / Row Pct / Col Pct / Tot Pct

JOBSIZE	three bidders 3	four bidders 4	five bidders 5	six bidders 6	seven bidders 7	eight bidders 8	nine bidders 9	ten bidders 10	Row Total
1 < £0.10 M	38 38.0 8.0 1.7	29 29.0 5.4 1.3	25 25.0 4.3 1.1	8 8.0 1.8 .4					100 4.4
2 £0.10 M - £0.25	168 32.7 35.3 7.4	158 30.8 29.6 7.0	111 21.6 19.1 4.9	64 12.5 14.2 2.8	8 1.6 6.6 .4	4 .8 6.5 .2			513 22.7
3 £0.25 M - £0.50	149 22.0 31.3 6.6	180 26.6 33.7 8.0	181 26.8 31.2 8.0	116 17.2 25.8 5.1	31 4.6 25.4 1.4	17 2.5 27.4 .8	2 .3 8.3 .1		676 29.9
4 £0.50 M - £0.75	52 15.4 10.9 2.3	60 17.8 11.2 2.7	97 28.7 16.7 4.3	86 25.4 19.1 3.8	27 8.0 22.1 1.2	15 4.4 24.2 .7	1 .3 4.2 .0		338 14.9
5 £0.75 M - £1.00	29 16.1 6.1 1.3	36 20.0 6.7 1.6	40 22.2 6.9 1.8	54 30.0 12.0 2.4	11 6.1 9.0 .5	7 3.9 11.3 .3	2 1.1 8.3 .1	1 .6 7.7 .0	180 8.0
6 £1.00 M - £1.25	12 8.3 2.5 .5	26 18.1 4.9 1.1	42 29.2 7.2 1.9	44 30.6 9.8 1.9	12 8.3 9.8 .5	5 3.5 8.1 .2	2 1.4 8.3 .1	1 .7 7.7 .0	144 6.4
7 £1.25 M - £1.50	9 11.5 1.9 .4	9 11.5 1.7 .4	23 29.5 4.0 1.0	19 24.4 4.2 .8	6 7.7 4.9 .3	4 5.1 6.5 .2	4 5.1 16.7 .2	4 5.1 30.8 .2	78 3.4
8 £1.50 M - £1.75	5 9.3 1.1 .2	12 22.2 2.2 .5	8 14.8 1.4 .4	14 25.9 3.1 .6	10 18.5 8.2 .4	2 3.7 3.2 .1	2 3.7 8.3 .1	1 1.9 7.7 .0	54 2.4
Column Total (Continued)	476 21.1	534 23.6	580 25.7	450 19.9	122 5.4	62 2.7	24 1.1	13 .6	2261 100.0

JOBSIZE size of job by NOBID number of bidders

NOBID — Page 2 of 2

Count / Row Pct / Col Pct / Tot Pct

JOBSIZE	three bidders 3	four bidders 4	five bidders 5	six bidders 6	seven bidders 7	eight bidders 8	nine bidders 9	ten bidders 10	Row Total
9 £1.75 M - £2.00	4 10.0 .8 .2	4 10.0 .7 .2	16 40.0 2.8 .7	9 22.5 2.0 .4	2 5.0 1.6 .1		4 10.0 16.7 .2	1 2.5 7.7 .0	40 1.8
10 £2.00 M - £2.25	2 5.6 .4 .1	9 25.0 1.7 .4	12 33.3 2.1 .5	10 27.8 2.2 .4	1 2.8 .8 .0	1 2.8 1.6 .0		1 2.8 7.7 .0	36 1.6
11 £2.25 M - £2.50	2 9.1 .4 .1	1 4.5 .2 .0	5 22.7 .9 .2	7 31.8 1.6 .3	4 18.2 3.3 .2	1 4.5 1.6 .0	2 9.1 8.3 .1		22 1.0
12 £2.50 M - £2.75		1 9.1 .2 .0	2 18.2 .3 .1	5 45.5 1.1 .2	1 9.1 .8 .0	1 9.1 1.6 .0	1 9.1 4.2 .0		11 .5
13 £2.75 M - £3.00	2 10.5 .4 .1	2 10.5 .4 .1	6 31.6 1.0 .3	4 21.1 .9 .2	3 15.8 2.5 .1	2 10.5 3.2 .1			19 .8
14 > £3.00 M	4 8.0 .8 .2	7 14.0 1.3 .3	12 24.0 2.1 .5	10 20.0 2.2 .4	6 12.0 4.9 .3	3 6.0 4.8 .1	4 8.0 16.7 .2	4 8.0 30.8 .2	50 2.2
Column Total	476 21.1	534 23.6	580 25.7	450 19.9	122 5.4	62 2.7	24 1.1	13 .6	2261 100.0

Number of Missing Observations: 0

As illustrated in table 9.19, there are generally more bidders competing for large value contracts (over £750,000) in refurbishment work. This is clearly indicated by the relatively high proportion of contracts having more than seven bidders in competition for jobs over £750,000. While there are much fewer contracts with more than seven bidders competing in smaller refurbishment jobs (less than £750,000). Thus, the distributional pattern of tender bids for different job sizes and number of bidders shows that refurbishment contracts which are over £750,000 have higher intensity of competition as compared to those below £750,000.

b) Number of bidders by job type

As depicted in table 9.20, there are not many contracts in industrial, recreation and religious buildings with more than seven bidders in competition. This implies that such contracts are comparatively less competitive in nature (fewer bidders). This result is supported by the interview of twenty-two refurbishment contractors in London by this researcher. Generally, most contractors are not keen to tender for the above three types of buildings. Industrial buildings are relatively simple jobs which normally do provide enough scope for making clear profit. Most of these contracts are also located outside London which are sometimes outside the operating zone of many contractors.

On the other hand, the refurbishment of religious and recreation buildings is more complex. Such work usually involves a high proportion of specialist work (religious buildings) or extensive protective measures such as noise and dust protection (recreation and refreshment buildings) which are often required due to the presence of occupants and passers-by. These additional provisions often involve more risks and added complexity thus deterring some contractors from tendering.

From table 9.20, it can be observed that there are generally more contracts with more than seven bidders in office and administration, education, scientific and information, and residential buildings. This simply implies that these three types of buildings are relatively more competitive in nature.

Table 9.20 : Cross-tabulation of tender bids by number of bidders and job type

JOBTYPE type of job by NOBID number of bidders

NOBID Page 1 of 1

JOBTYPE	Count Row Pct Col Pct Tot Pct	three bidders 3	four bidders 4	five bidders 5	six bidders 6	seven bidders 7	eight bidders 8	nine bidders 9	ten bidders 10	Row Total
Transport	1	31	24	27	24	11	3	1	1	122
		25.4	19.7	22.1	19.7	9.0	2.5	.8	.8	5.4
		6.5	4.5	4.7	5.3	9.0	4.8	4.2	7.7	
		1.4	1.1	1.2	1.1	.5	.1	.0	.0	
Industrial	2	14	14	17	15	1	5			66
		21.2	21.2	25.8	22.7	1.5	7.6			2.9
		2.9	2.6	2.9	3.3	.8	8.1			
		.6	.6	.8	.7	.0	.2			
Office	3	145	165	145	120	44	14	3	4	640
		22.7	25.8	22.7	18.8	6.9	2.2	.5	.6	28.3
		30.5	30.9	25.0	26.7	36.1	22.6	12.5	30.8	
		6.4	7.3	6.4	5.3	1.9	.6	.1	.2	
Health	4	36	33	42	46	9	4	5		175
		20.6	18.9	24.0	26.3	5.1	2.3	2.9		7.7
		7.6	6.2	7.2	10.2	7.4	6.5	20.8		
		1.6	1.5	1.9	2.0	.4	.2	.2		
Recreation	5	18	33	28	27	4	2			112
		16.1	29.5	25.0	24.1	3.6	1.8			5.0
		3.8	6.2	4.8	6.0	3.3	3.2			
		.8	1.5	1.2	1.2	.2	.1			
Religious	6	6	5	10	4	2				27
		22.2	18.5	37.0	14.8	7.4				1.2
		1.3	.9	1.7	.9	1.6				
		.3	.2	.4	.2	.1				
Education	7	38	61	82	57	15	13	6	4	276
		13.8	22.1	29.7	20.7	5.4	4.7	2.2	1.4	12.2
		8.0	11.4	14.1	12.7	12.3	21.0	25.0	30.8	
		1.7	2.7	3.6	2.5	.7	.6	.3	.2	
Residential	8	188	199	229	157	36	21	9	4	843
		22.3	23.6	27.2	18.6	4.3	2.5	1.1	.5	37.3
		39.5	37.3	39.5	34.9	29.5	33.9	37.5	30.8	
		8.3	8.8	10.1	6.9	1.6	.9	.4	.2	
Column Total		476	534	580	450	122	62	24	13	2261
		21.1	23.6	25.7	19.9	5.4	2.7	1.1	.6	100.0

Number of Missing Observations: 0

c) Number of bidders by year of tender

Although the one-way analysis of variance test (as shown in table 9.6) indicates that the population means of the number of bidders differ for different years, the distribution of contracts with various bidders for each year (1984 to 1989) appears to be quite similar as exhibited in table 9.21. Generally, most refurbishment contracts have three to six bidders in competition in all years. However, in some years there are more jobs with fewer or more bidders as compared to other years. For instance, as illustrated in table 9.21, there are relatively more contracts with five and six bidders for 1986 and 1989. This simply implies that competition was relatively more intense for these two years.

Table 9.21 : Cross-tabulation of tender bids by number of bidders and year of tender

YEAR year which bid is submitted by NOBID number of bidders

NOBID Page 1 of 1

YEAR		Count / Row Pct / Col Pct / Tot Pct	three bidders 3	four bidders 4	five bidders 5	six bidders 6	seven bidders 7	eight bidders 8	nine bidders 9	ten bidders 10	Row Total
1984	2	Count	106	114	100	72	20	5	3	1	421
		Row Pct	25.2	27.1	23.8	17.1	4.8	1.2	.7	.2	18.6
		Col Pct	22.3	21.3	17.2	16.0	16.4	8.1	12.5	7.7	
		Tot Pct	4.7	5.0	4.4	3.2	.9	.2	.1	.0	
1985	3	Count	110	124	120	118	27	17	6	2	524
		Row Pct	21.0	23.7	22.9	22.5	5.2	3.2	1.1	.4	23.2
		Col Pct	23.1	23.2	20.7	26.2	22.1	27.4	25.0	15.4	
		Tot Pct	4.9	5.5	5.3	5.2	1.2	.8	.3	.1	
1986	4	Count	38	47	68	59	20	13	3	2	250
		Row Pct	15.2	18.8	27.2	23.6	8.0	5.2	1.2	.8	11.1
		Col Pct	8.0	8.8	11.7	13.1	16.4	21.0	12.5	15.4	
		Tot Pct	1.7	2.1	3.0	2.6	.9	.6	.1	.1	
1987	5	Count	135	156	144	101	31	17	5	6	595
		Row Pct	22.7	26.2	24.2	17.0	5.2	2.9	.8	1.0	26.3
		Col Pct	28.4	29.2	24.8	22.4	25.4	27.4	20.8	46.2	
		Tot Pct	6.0	6.9	6.4	4.5	1.4	.8	.2	.3	
1988	6	Count	72	73	118	68	14	7	5	2	359
		Row Pct	20.1	20.3	32.9	18.9	3.9	1.9	1.4	.6	15.9
		Col Pct	15.1	13.7	20.3	15.1	11.5	11.3	20.8	15.4	
		Tot Pct	3.2	3.2	5.2	3.0	.6	.3	.2	.1	
1989	7	Count	15	20	30	32	10	3	2		112
		Row Pct	13.4	17.9	26.8	28.6	8.9	2.7	1.8		5.0
		Col Pct	3.2	3.7	5.2	7.1	8.2	4.8	8.3		
		Tot Pct	.7	.9	1.3	1.4	.4	.1	.1		
		Column Total	476	534	580	450	122	62	24	13	2261
			21.1	23.6	25.7	19.9	5.4	2.7	1.1	.6	100.0

Number of Missing Observations: 0

d) Bid spread by job size

Table 9.22 shows that bid spread of tender bids varies considerably in refurbishment work especially for contracts which are less than £750,000. The bid spread of these contracts ranges from 0% to over 14%. There is also a high proportion of small contracts (less than £500,000) with bid spread over 14% as displayed in table 9.22. One plausible reason for this pattern could be attributed to the mix of competition in small refurbishment contracts. Very often, these contracts are tendered by small builders of varying abilities. These contractors vary considerably in their pricing and tendering policies. As a result, contracts are sometimes secured with large win margin (bid spread).

Another possible reason for the high bid spread in smaller contracts could be due to new contractors entering the refurbishment market. This is commonly practiced by large contractors who set up refurbishment subsidiaries to expand their construction activities into the refurbishment market. As part of their learning curve, these subsidiaries are willing to undertake particularly small contracts at low prices which are sometimes below cost.

As remarked by one small refurbishment contractor who frequently tenders for contracts between £100,000 to £500,000:-

"You always tend to meet one or more unknown contractors competing in this job range."

Table 9.22 also shows that there is generally less "money left on the table" (bid spread) by contractors for larger contracts. This pattern is more discernible for jobs over £2m. In fact, as illustrated in table 9.22, many large refurbishment contracts are secured with bid spread between 0% to 4%. As explained before, this is mainly attributed to the comparability of contractors tendering in this job range. Large firms are more systematic and efficient in pricing and also have quite similar costs of production thus resulting in closer tender bids.

e) Bid spread by job type

From table 9.23, it is observed that all categories of job types have a large proportion of contracts (between 60% to 70% of all contracts) with bid spread between 0% to 6%. Generally, the distribution of jobs with different bid spread is quite similar for different job types. Comparing the distribution (row percentages in table 9.23) of contracts for different job types, industrial buildings seem to have a higher proportion of jobs (34.8%)

Table 9.22 : Cross-tabulation of tender bids by bid spread and job size

JOBSIZE size of job by SPREAD

SPREAD

JOBSIZE	Count / Row Pct / Col Pct / Tot Pct	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	Row Total
1	Count	14	13	16	7	8	10	8	24	100
< £0.10 M	Row Pct	14.0	13.0	16.0	7.0	8.0	10.0	8.0	24.0	4.4
	Col Pct	2.3	2.6	4.5	2.9	5.6	9.4	10.7	10.6	
	Tot Pct	.6	.6	.7	.3	.4	.4	.4	1.1	
2	Count	108	94	71	56	35	29	25	95	513
£0.10 M - £0.25	Row Pct	21.1	18.3	13.8	10.9	6.8	5.7	4.9	18.5	22.7
	Col Pct	17.8	18.7	19.9	23.2	24.5	27.4	33.3	41.9	
	Tot Pct	4.8	4.2	3.1	2.5	1.5	1.3	1.1	4.2	
3	Count	164	138	113	83	53	35	23	67	676
£0.25 M - £0.50	Row Pct	24.3	20.4	16.7	12.3	7.8	5.2	3.4	9.9	29.9
	Col Pct	27.0	27.4	31.7	34.4	37.1	33.0	30.7	29.5	
	Tot Pct	7.3	6.1	5.0	3.7	2.3	1.5	1.0	3.0	
4	Count	107	72	59	38	22	13	4	23	338
£0.50 M - £0.75	Row Pct	31.7	21.3	17.5	11.2	6.5	3.8	1.2	6.8	14.9
	Col Pct	17.6	14.3	16.5	15.8	15.4	12.3	5.3	10.1	
	Tot Pct	4.7	3.2	2.6	1.7	1.0	.6	.2	1.0	
5	Count	54	52	33	20	7	4	4	6	180
£0.75 M - £1.00	Row Pct	30.0	28.9	18.3	11.1	3.9	2.2	2.2	3.3	8.0
	Col Pct	8.9	10.3	9.2	8.3	4.9	3.8	5.3	2.6	
	Tot Pct	2.4	2.3	1.5	.9	.3	.2	.2	.3	
6	Count	56	35	22	13	4	7	5	2	144
£1.00 M - £1.25	Row Pct	38.9	24.3	15.3	9.0	2.8	4.9	3.5	1.4	6.4
	Col Pct	9.2	6.9	6.2	5.4	2.8	6.6	6.7	.9	
	Tot Pct	2.5	1.5	1.0	.6	.2	.3	.2	.1	
7	Count	20	20	16	5	7	4	3	3	78
£1.25 M - £1.50	Row Pct	25.6	25.6	20.5	6.4	9.0	5.1	3.8	3.8	3.4
	Col Pct	3.3	4.0	4.5	2.1	4.9	3.8	4.0	1.3	
	Tot Pct	.9	.9	.7	.2	.3	.2	.1	.1	
8	Count	16	21	5	5	1	1	2	3	54
£1.50 M - £1.75	Row Pct	29.6	38.9	9.3	9.3	1.9	1.9	3.7	5.6	2.4
	Col Pct	2.6	4.2	1.4	2.1	.7	.9	2.7	1.3	
	Tot Pct	.7	.9	.2	.2	.0	.0	.1	.1	
(Continued)	Column Total	608	504	357	241	143	106	75	227	2261
		26.9	22.3	15.8	10.7	6.3	4.7	3.3	10.0	100.0

JOBSIZE size of job by SPREAD

SPREAD

JOBSIZE	Count / Row Pct / Col Pct / Tot Pct	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	Row Total
9	Count	12	16	6	2	2	1		1	40
£1.75 M - £2.00	Row Pct	30.0	40.0	15.0	5.0	5.0	2.5		2.5	1.8
	Col Pct	2.0	3.2	1.7	.8	1.4	.9		.4	
	Tot Pct	.5	.7	.3	.1	.1	.0		.0	
10	Count	7	20	5	3		1			36
£2.00 M - £2.25	Row Pct	19.4	55.6	13.9	8.3		2.8			1.6
	Col Pct	1.2	4.0	1.4	1.2		.9			
	Tot Pct	.3	.9	.2	.1		.0			
11	Count	7	6	3	1	3			2	22
£2.25 M - £2.50	Row Pct	31.8	27.3	13.6	4.5	13.6			9.1	1.0
	Col Pct	1.2	1.2	.8	.4	2.1			.9	
	Tot Pct	.3	.3	.1	.0	.1			.1	
12	Count	6	1	1	2		1			11
£2.50 M - £2.75	Row Pct	54.5	9.1	9.1	18.2		9.1			.5
	Col Pct	1.0	.2	.3	.8		.9			
	Tot Pct	.3	.0	.0	.1		.0			
13	Count	11	2	2	2	1		1		19
£2.75 M - £3.00	Row Pct	57.9	10.5	10.5	10.5	5.3		5.3		.8
	Col Pct	1.8	.4	.6	.8	.7		1.3		
	Tot Pct	.5	.1	.1	.1	.0		.0		
14	Count	26	14	5	4				1	50
> £3.00 M	Row Pct	52.0	28.0	10.0	8.0				2.0	2.2
	Col Pct	4.3	2.8	1.4	1.7				.4	
	Tot Pct	1.1	.6	.2	.2				.0	
	Column Total	608	504	357	241	143	106	75	227	2261
		26.9	22.3	15.8	10.7	6.3	4.7	3.3	10.0	100.0

Number of Missing Observations: 0

(Note: Please refer to table 6.2 for classification of bid spread) with bid spread less than 2%. This pattern is probably attributed to the job characteristics of industrial buildings. The refurbishment of industrial buildings is usually simple and involves fewer risks. Thus, contractors are able to estimate the cost of construction more accurately. As a result, tender bids are comparatively close to one another, resulting in lower bid spread.

Table 9.23: Cross-tabulation of tender bids by bid spread and job type

JOBTYPE type of job by SPREAD

Page 1 of 1

JOBTYPE	SPREAD: Count / Row Pct / Col Pct / Tot Pct	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	Row Total
1 Transport	Count	41	25	22	7	5	9	1	12	122
	Row Pct	33.6	20.5	18.0	5.7	4.1	7.4	.8	9.8	5.4
	Col Pct	6.7	5.0	6.2	2.9	3.5	8.5	1.3	5.3	
	Tot Pct	1.8	1.1	1.0	.3	.2	.4	.0	.5	
2 Industrial	Count	23	12	11	7	3	3	1	6	66
	Row Pct	34.8	18.2	16.7	10.6	4.5	4.5	1.5	9.1	2.9
	Col Pct	3.8	2.4	3.1	2.9	2.1	2.8	1.3	2.6	
	Tot Pct	1.0	.5	.5	.3	.1	.1	.0	.3	
3 Office	Count	189	171	79	75	40	21	16	49	640
	Row Pct	29.5	26.7	12.3	11.7	6.3	3.3	2.5	7.7	28.3
	Col Pct	31.1	33.9	22.1	31.1	28.0	19.8	21.3	21.6	
	Tot Pct	8.4	7.6	3.5	3.3	1.8	.9	.7	2.2	
4 Health	Count	51	36	30	18	10	11	5	14	175
	Row Pct	29.1	20.6	17.1	10.3	5.7	6.3	2.9	8.0	7.7
	Col Pct	8.4	7.1	8.4	7.5	7.0	10.4	6.7	6.2	
	Tot Pct	2.3	1.6	1.3	.8	.4	.5	.2	.6	
5 Recreation	Count	38	23	16	11	2	7	4	11	112
	Row Pct	33.9	20.5	14.3	9.8	1.8	6.3	3.6	9.8	5.0
	Col Pct	6.3	4.6	4.5	4.6	1.4	6.6	5.3	4.8	
	Tot Pct	1.7	1.0	.7	.5	.1	.3	.2	.5	
6 Religious	Count	5	5	7	3	2	2		3	27
	Row Pct	18.5	18.5	25.9	11.1	7.4	7.4		11.1	1.2
	Col Pct	.8	1.0	2.0	1.2	1.4	1.9		1.3	
	Tot Pct	.2	.2	.3	.1	.1	.1		.1	
7 Education	Count	87	56	45	27	16	10	14	21	276
	Row Pct	31.5	20.3	16.3	9.8	5.8	3.6	5.1	7.6	12.2
	Col Pct	14.3	11.1	12.6	11.2	11.2	9.4	18.7	9.3	
	Tot Pct	3.8	2.5	2.0	1.2	.7	.4	.6	.9	
8 Residential	Count	174	176	147	93	65	43	34	111	843
	Row Pct	20.6	20.9	17.4	11.0	7.7	5.1	4.0	13.2	37.3
	Col Pct	28.6	34.9	41.2	38.6	45.5	40.6	45.3	48.9	
	Tot Pct	7.7	7.8	6.5	4.1	2.9	1.9	1.5	4.9	
Column Total		608	504	357	241	143	106	75	227	2261
		26.9	22.3	15.8	10.7	6.3	4.7	3.3	10.0	100.0

Number of Missing Observations: 0

On the other hand, the category of residential buildings tends to have comparatively more of its contracts (13.2% of all residential contracts) with bid spread over 14% as illustrated in table 9.23. Again, this is also mainly attributed to the complex nature of such work and the heterogeneous mix of contractors competing for such contracts. Projects with high complexity often result in wide dispersion of tender bids and consequently larger bid spread. This is mainly due to differences in the assessment of risks among contractors.

f) Bid spread by year of tender

There is no discernible bidding pattern observed in the distribution of contracts as displayed by the cross-tabulation of bid spread and year of tender. The distributions of jobs as illustrated in table 9.24 are very similar throughout 1984 to 1989. In all years, there is generally a large proportion of bids being secured with bid spread between 0% to 6%. This indicates that many refurbishment contracts were secured by contractors leaving too much "money on the table".

Table 9.24 : Cross-tabulation of tender bids by bid spread and year of tender

YEAR year which bid is submitted by SPREAD

SPREAD — Page 1 of 1

YEAR	Count / Row Pct / Col Pct / Tot Pct	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	Row Total
1984	2	113	106	57	47	30	14	16	38	421
		26.8	25.2	13.5	11.2	7.1	3.3	3.8	9.0	18.6
		18.6	21.0	16.0	19.5	21.0	13.2	21.3	16.7	
		5.0	4.7	2.5	2.1	1.3	.6	.7	1.7	
1985	3	143	126	86	52	22	26	20	49	524
		27.3	24.0	16.4	9.9	4.2	5.0	3.8	9.4	23.2
		23.5	25.0	24.1	21.6	15.4	24.5	26.7	21.6	
		6.3	5.6	3.8	2.3	1.0	1.1	.9	2.2	
1986	4	75	60	40	22	19	9	6	19	250
		30.0	24.0	16.0	8.8	7.6	3.6	2.4	7.6	11.1
		12.3	11.9	11.2	9.1	13.3	8.5	8.0	8.4	
		3.3	2.7	1.8	1.0	.8	.4	.3	.8	
1987	5	156	120	100	67	43	25	16	68	595
		26.2	20.2	16.8	11.3	7.2	4.2	2.7	11.4	26.3
		25.7	23.8	28.0	27.8	30.1	23.6	21.3	30.0	
		6.9	5.3	4.4	3.0	1.9	1.1	.7	3.0	
1988	6	97	71	57	34	21	24	11	44	359
		27.0	19.8	15.9	9.5	5.8	6.7	3.1	12.3	15.9
		16.0	14.1	16.0	14.1	14.7	22.6	14.7	19.4	
		4.3	3.1	2.5	1.5	.9	1.1	.5	1.9	
1989	7	24	21	17	19	8	8	6	9	112
		21.4	18.8	15.2	17.0	7.1	7.1	5.4	8.0	5.0
		3.9	4.2	4.8	7.9	5.6	7.5	8.0	4.0	
		1.1	.9	.8	.8	.4	.4	.3	.4	
	Column Total	608	504	357	241	143	106	75	227	2261
		26.9	22.3	15.8	10.7	6.3	4.7	3.3	10.0	100.0

Number of Missing Observations: 0

g) Bid RD by job size

As displayed in table 9.25 there are generally more contracts in the lower job size range (below £500,000) with high bid RD over 18% than other job ranges. Table 9.25 also shows that 37% of all contracts which are less than £100,000 have bid spread over 18%. This trend is also observed in jobs between £100,000 to £250,000 which have 26% of its contracts with high bid RD (over 18%). This clustering of bids clearly shows that small refurbishment contracts have comparatively higher dispersion of bids as compared to larger contracts.

There is also a gradual decrease in the number of jobs with high bid RD as job size increases. This pattern is more discernible in contracts over £2m. This decreasing trend of bid RD is probably due to the mix of competition among contractors in different job sizes. Generally, smaller contracts tend to have a more heterogeneous mix of bidders (contractors of different 'calibre') and thus tender bids are more variable. However, as job size increases, the pool of contractors who are qualified to undertake such work become more comparable in terms of capability and capacity. As remarked by a number of refurbishment specialists:-

"Competition in larger contracts is much fairer as we are competing with contractors of similar calibre"

Under such circumstances, bids submitted by contractors are more closely grouped together resulting in lower bid dispersion. Thus, the cross-tabulation of contracts by bid RD and job size clearly shows that there are more small refurbishment contracts with high bid RD as compared to larger projects.

The decreasing trend of bid RD as project size increases is also supported by the results obtained by other researchers such as Quah (1), Park (2) and Skitmore (3). The main reason put forward by these researchers is that large contracts are normally tendered for by larger firms which are more systematic and efficient in their pricing thus resulting in less variation of bids. Furthermore, there is also a better mix of competition in larger contracts with contractors of similar 'calibre' competing. Thus, their costs of construction do not vary considerably. As a result, their tender bids are much closer.

Table 9.25 : Cross-tabulation of tender bids by bid RD and job size

JOBSIZE size of job by RD

Page 1 of 2

JOBSIZE	Count / Row Pct / Col Pct / Tot Pct	RD 1.00	2.00	3.00	4.00	5.00	6.00	7.00	Row Total
1 < £0.10 M	Count	1	4	10	10	21	17	37	100
	Row Pct	1.0	4.0	10.0	10.0	21.0	17.0	37.0	4.4
	Col Pct	.7	.8	1.9	2.8	7.8	10.6	10.8	
	Tot Pct	.0	.2	.4	.4	.9	.8	1.6	
2 £0.10 M - £0.25	Count	16	62	104	86	69	45	131	513
	Row Pct	3.1	12.1	20.3	16.8	13.5	8.8	25.5	22.7
	Col Pct	11.7	13.1	19.8	24.2	25.6	28.1	38.3	
	Tot Pct	.7	2.7	4.6	3.8	3.1	2.0	5.8	
3 £0.25 M - £0.50	Count	28	126	161	122	98	47	94	676
	Row Pct	4.1	18.6	23.8	18.0	14.5	7.0	13.9	29.9
	Col Pct	20.4	26.7	30.7	34.3	36.3	29.4	27.5	
	Tot Pct	1.2	5.6	7.1	5.4	4.3	2.1	4.2	
4 £0.50 M - £0.75	Count	27	83	88	47	35	24	34	338
	Row Pct	8.0	24.6	26.0	13.9	10.4	7.1	10.1	14.9
	Col Pct	19.7	17.6	16.8	13.2	13.0	15.0	9.9	
	Tot Pct	1.2	3.7	3.9	2.1	1.5	1.1	1.5	
5 £0.75 M - £1.00	Count	12	49	50	29	15	8	17	180
	Row Pct	6.7	27.2	27.8	16.1	8.3	4.4	9.4	8.0
	Col Pct	8.8	10.4	9.5	8.1	5.6	5.0	5.0	
	Tot Pct	.5	2.2	2.2	1.3	.7	.4	.8	
6 £1.00 M - £1.25	Count	15	42	29	26	9	9	14	144
	Row Pct	10.4	29.2	20.1	18.1	6.3	6.3	9.7	6.4
	Col Pct	10.9	8.9	5.5	7.3	3.3	5.6	4.1	
	Tot Pct	.7	1.9	1.3	1.1	.4	.4	.6	
7 £1.25 M - £1.50	Count	10	22	21	8	8	3	6	78
	Row Pct	12.8	28.2	26.9	10.3	10.3	3.8	7.7	3.4
	Col Pct	7.3	4.7	4.0	2.2	3.0	1.9	1.8	
	Tot Pct	.4	1.0	.9	.4	.4	.1	.3	
8 £1.50 M - £1.75	Count	5	14	17	9	5	4		54
	Row Pct	9.3	25.9	31.5	16.7	9.3	7.4		2.4
	Col Pct	3.6	3.0	3.2	2.5	1.9	2.5		
	Tot Pct	.2	.6	.8	.4	.2	.2		
(Continued)	Column Total	137	472	524	356	270	160	342	2261
		6.1	20.9	23.2	15.7	11.9	7.1	15.1	100.0

JOBSIZE size of job by RD

Page 2 of 2

JOBSIZE	Count / Row Pct / Col Pct / Tot Pct	RD 1.00	2.00	3.00	4.00	5.00	6.00	7.00	Row Total
9 £1.75 M - £2.00	Count	8	15	13	1	2		1	40
	Row Pct	20.0	37.5	32.5	2.5	5.0		2.5	1.8
	Col Pct	5.8	3.2	2.5	.3	.7		.3	
	Tot Pct	.4	.7	.6	.0	.1		.0	
10 £2.00 M - £2.25	Count		16	4	8	1	3	4	36
	Row Pct		44.4	11.1	22.2	2.8	8.3	11.1	1.6
	Col Pct		3.4	.8	2.2	.4	1.9	1.2	
	Tot Pct		.7	.2	.4	.0	.1	.2	
11 £2.25 M - £2.50	Count	1	7	4	4	5		1	22
	Row Pct	4.5	31.8	18.2	18.2	22.7		4.5	1.0
	Col Pct	.7	1.5	.8	1.1	1.9		.3	
	Tot Pct	.0	.3	.2	.2	.2		.0	
12 £2.50 M - £2.75	Count	2	3	4	1	1			11
	Row Pct	18.2	27.3	36.4	9.1	9.1			.5
	Col Pct	1.5	.6	.8	.3	.4			
	Tot Pct	.1	.1	.2	.0	.0			
13 £2.75 M - £3.00	Count	1	6	9	2			1	19
	Row Pct	5.3	31.6	47.4	10.5			5.3	.8
	Col Pct	.7	1.3	1.7	.6			.3	
	Tot Pct	.0	.3	.4	.1			.0	
14 > £3.00 M	Count	11	23	10	3	1		2	50
	Row Pct	22.0	46.0	20.0	6.0	2.0		4.0	2.2
	Col Pct	8.0	4.9	1.9	.8	.4		.6	
	Tot Pct	.5	1.0	.4	.1	.0		.1	
	Column Total	137	472	524	356	270	160	342	2261
		6.1	20.9	23.2	15.7	11.9	7.1	15.1	100.0

Number of Missing Observations: 0

(Note: Please refer to table 6.1 for classification of bid RD)

h) Bid RD by job type

From table 9.26, it is observed that there is a large proportion of contracts (between 35% to 50%) in each job type category with bid RD between 3% to 9%. The comparison of row percentages among different job types reveals that industrial buildings have the highest percentage of its contracts (10.6%) with bid RD of less than 3%.

While only 3% of residential contracts and 3.7% of religious building contracts have bid RD of less than 3%. This clearly shows that tender bids in industrial buildings are generally less dispersed than those in residential and religious buildings. As explained before, this is mainly due to the nature of these jobs and the mix of competition.

Table 9.26 : Cross-tabulation of tender bids by bid RD and job type

JOBTYPE type of job by RD

Page 1 of 1

JOBTYPE	RD: Count / Row Pct / Col Pct / Tot Pct	1.00	2.00	3.00	4.00	5.00	6.00	7.00	Row Total
1 Transport	Count	11	26	35	11	9	9	21	122
	Row Pct	9.0	21.3	28.7	9.0	7.4	7.4	17.2	5.4
	Col Pct	8.0	5.5	6.7	3.1	3.3	5.6	6.1	
	Tot Pct	.5	1.1	1.5	.5	.4	.4	.9	
2 Industrial	Count	7	14	16	9	11	3	6	66
	Row Pct	10.6	21.2	24.2	13.6	16.7	4.5	9.1	2.9
	Col Pct	5.1	3.0	3.1	2.5	4.1	1.9	1.8	
	Tot Pct	.3	.6	.7	.4	.5	.1	.3	
3 Office	Count	58	158	156	91	77	32	68	640
	Row Pct	9.1	24.7	24.4	14.2	12.0	5.0	10.6	28.3
	Col Pct	42.3	33.5	29.8	25.6	28.5	20.0	19.9	
	Tot Pct	2.6	7.0	6.9	4.0	3.4	1.4	3.0	
4 Health	Count	10	35	43	24	21	16	26	175
	Row Pct	5.7	20.0	24.6	13.7	12.0	9.1	14.9	7.7
	Col Pct	7.3	7.4	8.2	6.7	7.8	10.0	7.6	
	Tot Pct	.4	1.5	1.9	1.1	.9	.7	1.1	
5 Recreation	Count	5	29	26	18	15	10	9	112
	Row Pct	4.5	25.9	23.2	16.1	13.4	8.9	8.0	5.0
	Col Pct	3.6	6.1	5.0	5.1	5.6	6.3	2.6	
	Tot Pct	.2	1.3	1.1	.8	.7	.4	.4	
6 Religious	Count	1	4	6	6	5	2	3	27
	Row Pct	3.7	14.8	22.2	22.2	18.5	7.4	11.1	1.2
	Col Pct	.7	.8	1.1	1.7	1.9	1.3	.9	
	Tot Pct	.0	.2	.3	.3	.2	.1	.1	
7 Education	Count	20	77	71	44	27	15	22	276
	Row Pct	7.2	27.9	25.7	15.9	9.8	5.4	8.0	12.2
	Col Pct	14.6	16.3	13.5	12.4	10.0	9.4	6.4	
	Tot Pct	.9	3.4	3.1	1.9	1.2	.7	1.0	
8 Residential	Count	25	129	171	153	105	73	187	843
	Row Pct	3.0	15.3	20.3	18.1	12.5	8.7	22.2	37.3
	Col Pct	18.2	27.3	32.6	43.0	38.9	45.6	54.7	
	Tot Pct	1.1	5.7	7.6	6.8	4.6	3.2	8.3	
Column Total		137	472	524	356	270	160	342	2261
		6.1	20.9	23.2	15.7	11.9	7.1	15.1	100.0

Number of Missing Observations: 0

The high dispersion of bids in residential buildings is also clearly reflected by the large percentage of its contracts having bid RD greater than 18% (22.2% of its contracts). Thus, the above analysis determines the proportion of contracts with various bid RD for various categories of job types in refurbishment work and thus provides useful feedback information to contractors in understanding bid dispersion for different job types.

i) Bid RD by year of tender

As illustrated in table 9.27, the distributions of contracts with varying bid RD for different years have quite similar profiles for all the years (1984 to 1989). Generally, most years have a large proportion of contracts (about 40% to 50%) with bid RD ranging between 3% to 9%. Comparing the row percentages of bids as illustrated in table 9.27, it is observed that 1985 has the highest percentage of jobs (18.7%) with bid RD over 18%. This indicates that more jobs have wide dispersion of bids within the contract in 1985 than other years. On the other hand, there are comparatively fewer jobs (9.6%) in 1986 with high bid RD (over 18%). This observation of bid RD variation between these two years is also confirmed by the Scheffe test as shown in appendix D. Thus, the tabulation of bid RD by year of tender displays the bid dispersion characteristics of tender bids for various years of tender. This analysis enables contractors to understand the variation of bids among different years. The dispersion of bids also provides a good indication of the existing market conditions.

9.3.4 Correlation analysis of bidding variables

In this analysis, scatterplots of major bidding variables such as bid range, bid RD, bid spread, job size and number of bidders were plotted to determine whether there is any association among these variables. The Pearson Product Moment Coefficient of correlation is adopted as a measure to determine the strength of linear association between the variables. The scatterplots of the above bidding variables were plotted as shown in appendix E. From the shape of the scatterplot (L-shape) and the low correlation

Table 9.27 : Cross-tabulation of tender bids by bid RD and year of tender

YEAR year which bid is submitted by RD

Page 1 of 1

YEAR	RD (Count / Row Pct / Col Pct / Tot Pct)	1.00	2.00	3.00	4.00	5.00	6.00	7.00	Row Total
1984	2	25	84	102	72	53	32	53	421
		5.9	20.0	24.2	17.1	12.6	7.6	12.6	18.6
		18.2	17.8	19.5	20.2	19.6	20.0	15.5	
		1.1	3.7	4.5	3.2	2.3	1.4	2.3	
1985	3	35	113	108	72	62	36	98	524
		6.7	21.6	20.6	13.7	11.8	6.9	18.7	23.2
		25.5	23.9	20.6	20.2	23.0	22.5	28.7	
		1.5	5.0	4.8	3.2	2.7	1.6	4.3	
1986	4	12	70	66	32	33	13	24	250
		4.8	28.0	26.4	12.8	13.2	5.2	9.6	11.1
		8.8	14.8	12.6	9.0	12.2	8.1	7.0	
		.5	3.1	2.9	1.4	1.5	.6	1.1	
1987	5	39	113	139	91	60	43	110	595
		6.6	19.0	23.4	15.3	10.1	7.2	18.5	26.3
		28.5	23.9	26.5	25.6	22.2	26.9	32.2	
		1.7	5.0	6.1	4.0	2.7	1.9	4.9	
1988	6	24	73	77	71	46	27	41	359
		6.7	20.3	21.4	19.8	12.8	7.5	11.4	15.9
		17.5	15.5	14.7	19.9	17.0	16.9	12.0	
		1.1	3.2	3.4	3.1	2.0	1.2	1.8	
1989	7	2	19	32	18	16	9	16	112
		1.8	17.0	28.6	16.1	14.3	8.0	14.3	5.0
		1.5	4.0	6.1	5.1	5.9	5.6	4.7	
		.1	.8	1.4	.8	.7	.4	.7	
	Column Total	137	472	524	356	270	160	342	2261
		6.1	20.9	23.2	15.7	11.9	7.1	15.1	100.0

Number of Missing Observations: 0

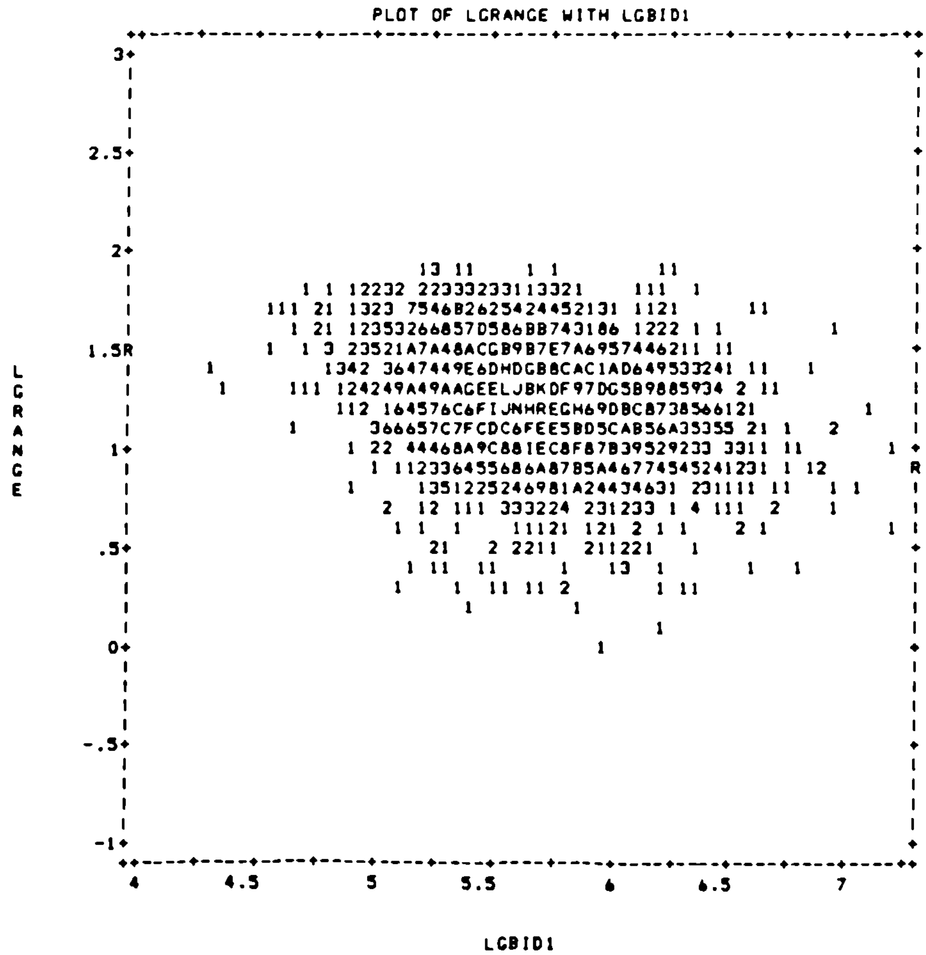
coefficients obtained, it seems necessary to transform the variables. Three main types of transformation (logarithm, inverse and square-root transformations) were used and it was found that the logarithm transformation of variables produced the most suitable scatterplots for analysis. The transformed scatterplots of various bidding variables are described below.

a) Scatterplot of logarithm bid range and logarithm job size (lowest bid)

As shown in figure 9.12, the scatterplot of logarithm bid range and logarithm job size has a negative correlation coefficient of -0.26. In order to determine whether there is significant association between the variables, we test the hypothesis at the 5% significance level that the true correlation coefficient is zero. We compare the modulus of r (correlation coefficient) with r(2.5) from the percentage points of correlation coefficient table as shown in appendix F. If the modulus of r is less than r(2.5), we accept the hypothesis that the true correlation coefficient is zero. Therefore, we have no statistical evidence that there is significant correlation between the variables.

Since the modulus of -0.26 is greater than 0.04 (value of r(2.5) from appendix F) with a degree of freedom of 2260, we have statistical evidence that there is significant linear correlation between logarithm bid range and logarithm job size. Although the correlation value of -0.26 shows a significant correlation, it only explains about 26% of the data (2261 cases). Thus, we can only conclude by stating that logarithm bid range has a significant but weak negative linear correlation with logarithm job size. That is, generally bid range decreases as job size increases.

Figure 9.12 : Scatterplot of log bid range and log job size

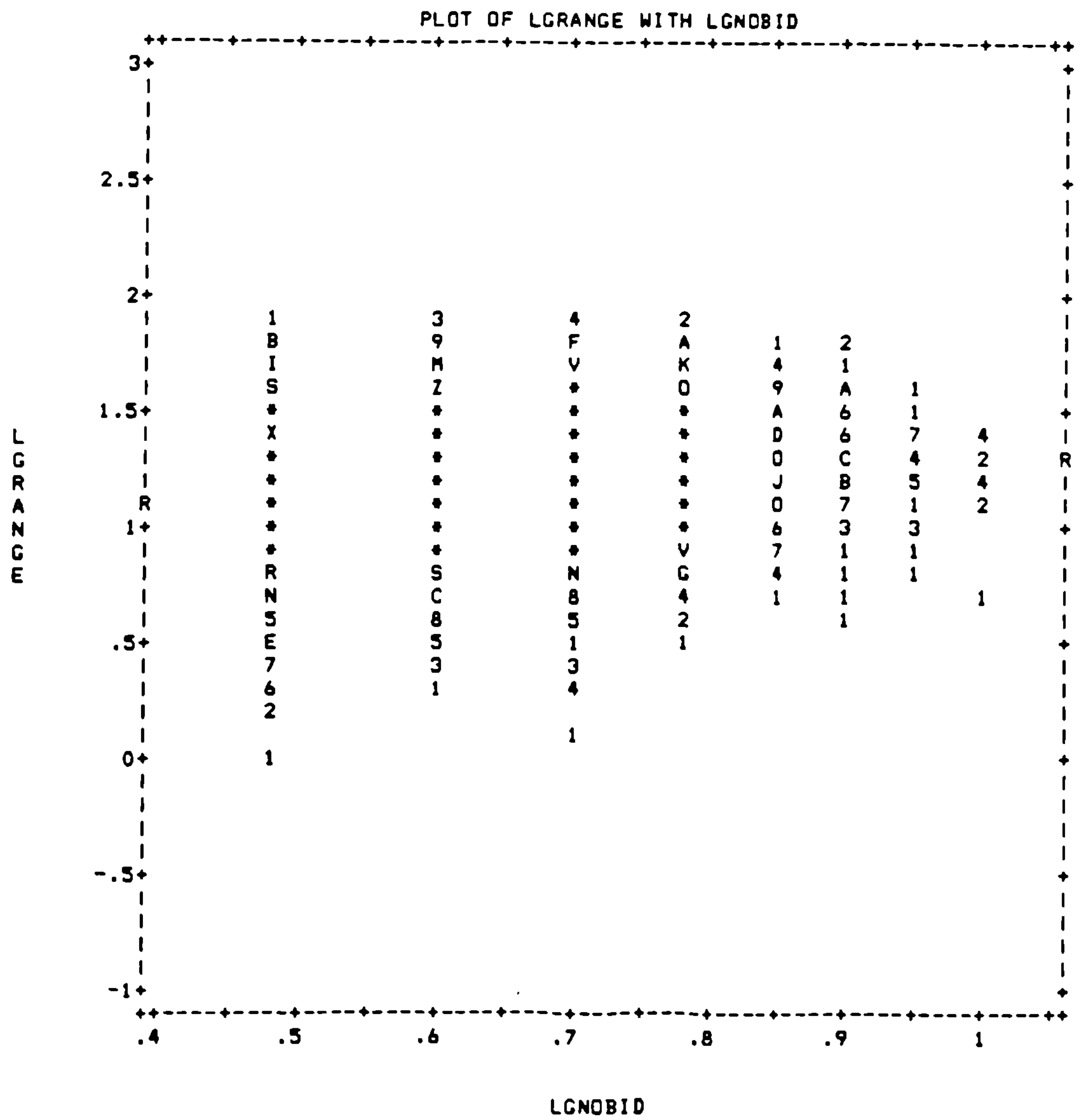



```
2261 cases plotted. Regression statistics of LCRANGE on LCBID1:
Correlation -.26135 R Squared   .06830  S.E. of Est      .28218 Sig.  .0000
Intercept(S.E.)     2.30559(    .08437)  Slope(S.E.)     -.18991(    .01476)
```

b) Scatterplot of logarithm bid range and logarithm number of bidders

The scatterplot of logarithm bid range and logarithm number of bidders as shown in figure 9.13 produces a correlation coefficient of 0.13. As compared to the statistical table value of 0.04 (degrees of freedom = 2260) at the 5% significance level, 0.13 is slightly greater than 0.04. Therefore, we have statistical evidence that there is significant but weak positive linear correlation between logarithm bid range and logarithm number of bidders at the 5% significance level.

Figure 9.13 : Scatterplot of log bid range and log number of bidders

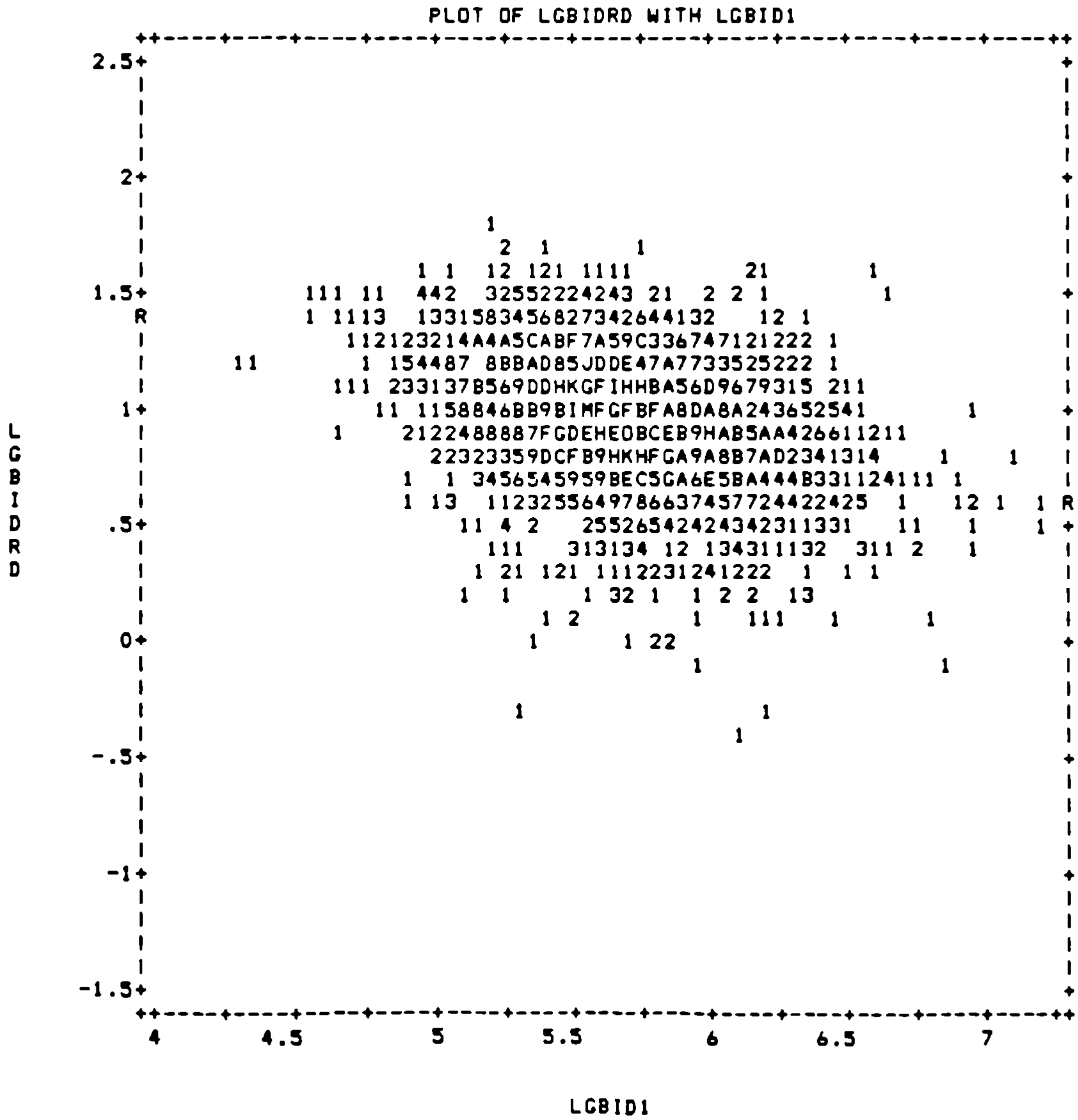


2261 cases plotted. Regression statistics of LGRANGE on LGNOBID:
Correlation .13468 R Squared .01814 S.E. of Est .28968 Sig. .0000
Intercept(S.E.) 1.01653(.03247) Slope(S.E.) .31070(.04809)

c) Scatterplot of logarithm bid RD and logarithm job size

The scatterplot of logarithm bid RD and logarithm job size as illustrated in figure 9.14 shows a correlation coefficient of -0.35. This value is significantly greater than 0.04 of the statistical table (appendix F). Therefore, we strong statistical evidence that there is significant negative linear correlation between logarithm bid RD and logarithm job size.

Figure 9.14 : Scatterplot of log bid RD and log job size

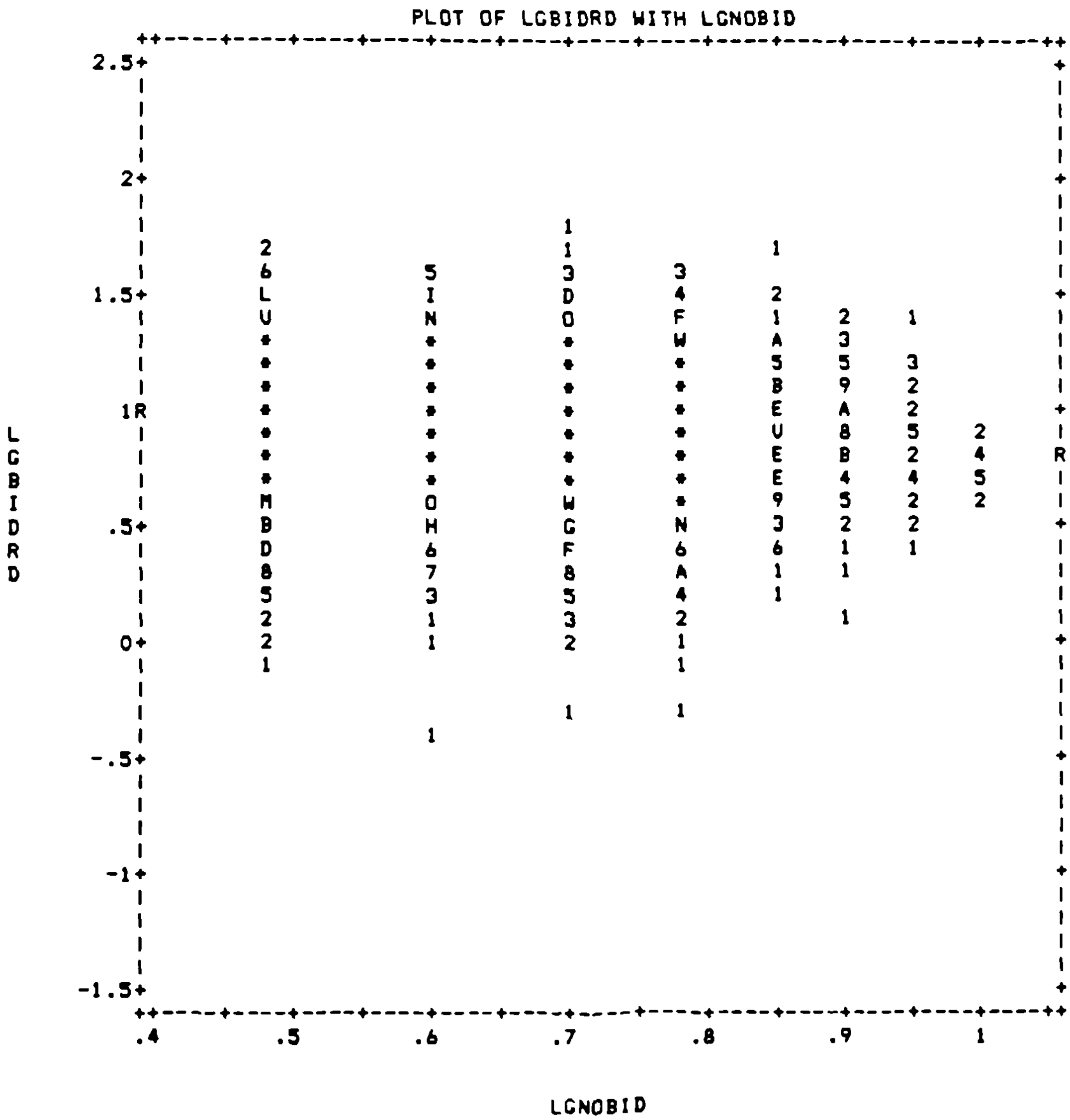



```
2261 cases plotted. Regression statistics of LGBIDRD on LGBID1:
Correlation -.34539 R Squared   .11929  S.E. of Est    .27765 Sig.  .0000
Intercept(S.E.)    2.39539(   .08301)   Slope(S.E.)    -.25400(   .01452)
```

d) Scatterplot of logarithm bid RD and logarithm number of bidders

Figure 9.15 displays the scatterplot of logarithm bid RD and logarithm number of bidders. A correlation coefficient of -0.12 was obtained which has a modulus slightly greater than 0.04 as shown in appendix F at the 5% significance level. Thus, we have statistical evidence that there is significant but weak negative linear correlation between logarithm bid RD and logarithm number of bidders at the 5% significance level.

Figure 9.15 : Scatterplot of log bid RD and log number of bidders

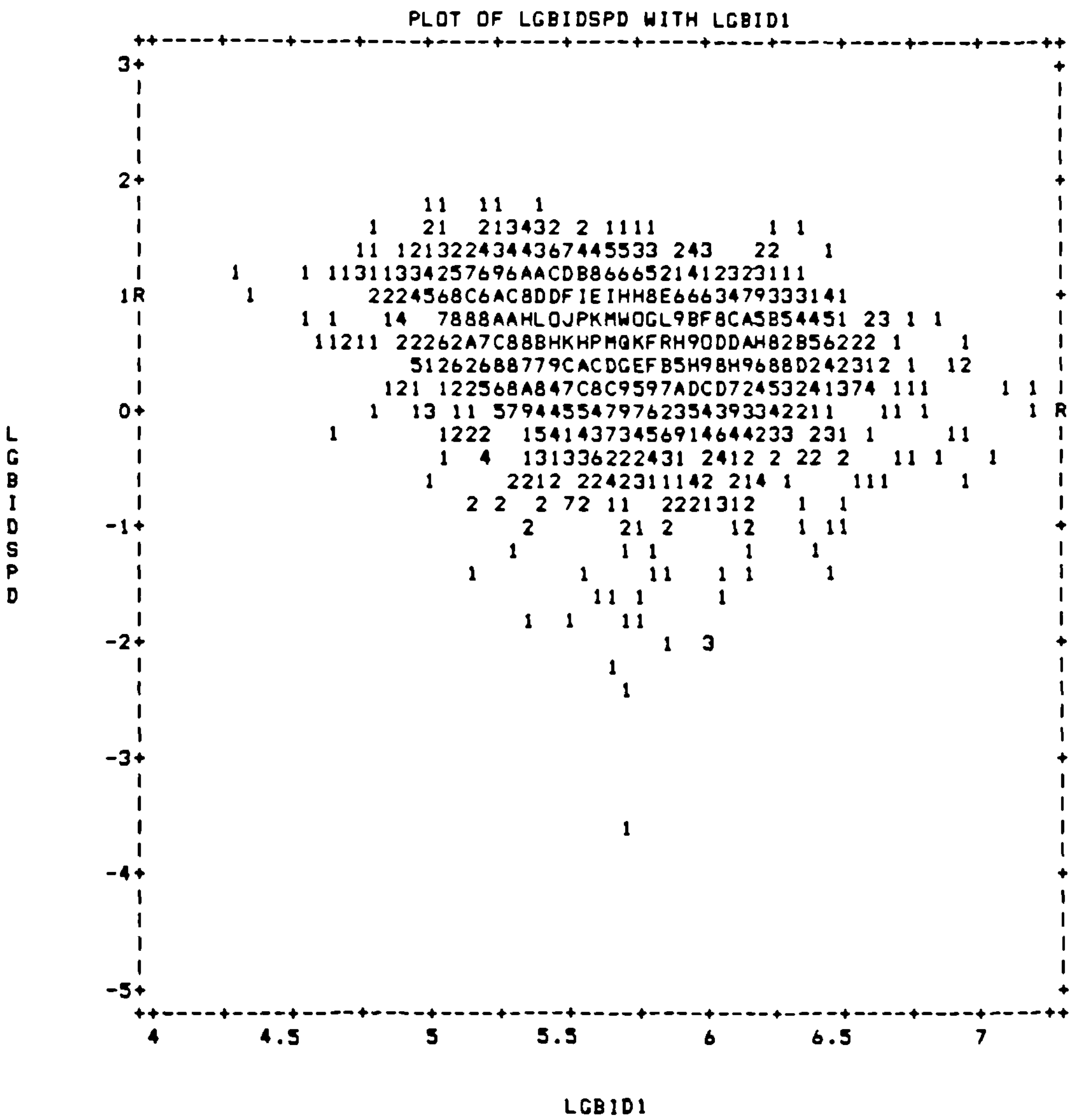


2261 cases plotted. Regression statistics of LGBIDRD on LGNOBID:
Correlation -.12200 R Squared .01488 S.E. of Est .29364 Sig. .0000
Intercept(S.E.) 1.13571(.03291) Slope(S.E.) -.28481(.04875)

e) **Scatterplot of logarithm bid spread and logarithm job size**

The scatterplot of logarithm bid spread and logarithm job size shows a negative linear correlation as displayed in figure 9.16. The correlation coefficient of -0.23 which has a modulus greater than 0.04 in the statistical table (appendix F). This indicates that we have statistical evidence that logarithm bid spread has a significant but weak negative linear correlation with logarithm job size at the 5% significance level.

Figure 9.16 : Scatterplot of log bid spread and log job size

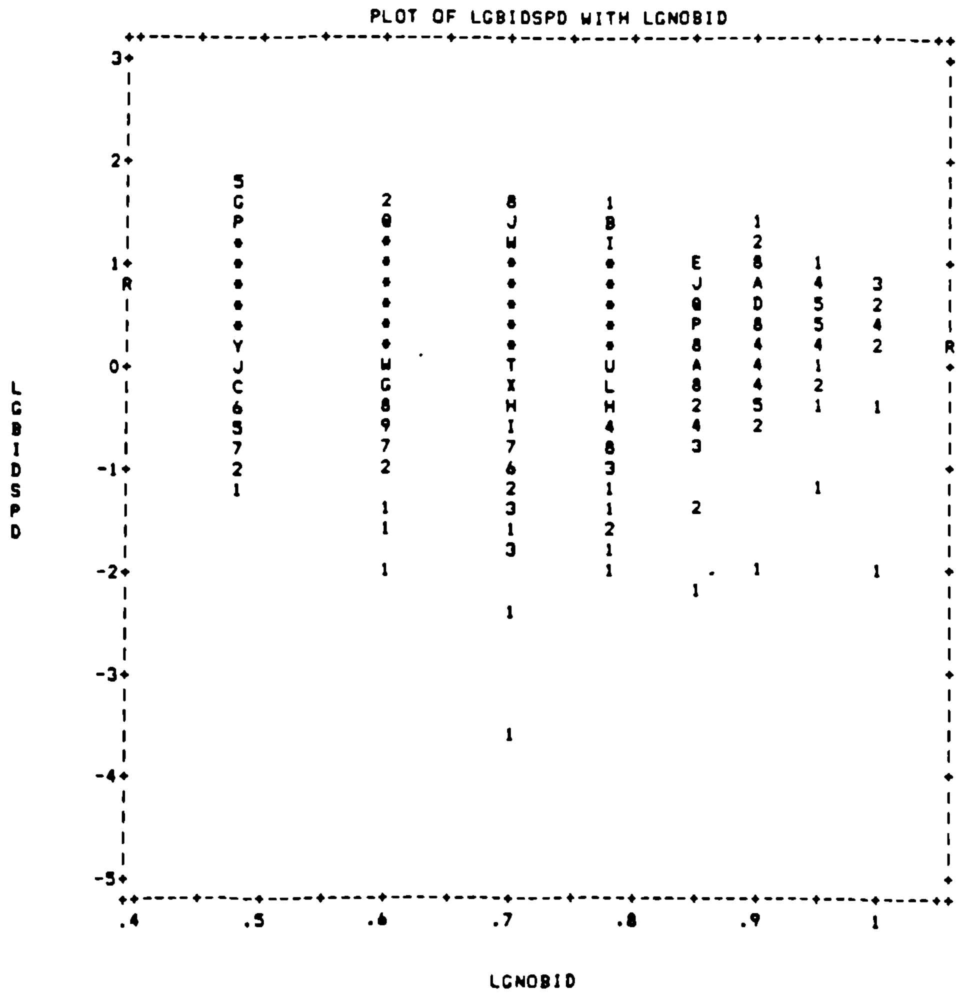



```
2259 cases plotted. Regression statistics of LGBIDSPD on LGBID1:
Correlation -.22867 R Squared  .05229  S.E. of Est   .54163 Sig.  .0000
Intercept(S.E.)    2.34071(   .16194)  Slope(S.E.)   -.31610(   .02833)
```

f) Scatterplot of logarithm bid spread and logarithm number of bidders

Figure 9.17 displays the scatterplot of logarithm bid spread and logarithm number of bidders. A correlation coefficient of -0.21 was obtained. The modulus of -0.21 is greater than 0.04 in the statistical table (appendix F). Thus, we have statistical evidence that logarithm bid spread has a significant but weak negative linear correlation with logarithm number of bidders in refurbishment work. That is, the bid spread of tender bids decreases as the number of bidders per job increases.

Figure 9.17 : Scatterplot of log bid spread and log number of bidders



2259 cases plotted. Regression statistics of LCBIDSPD on LCNOBID:
Correlation -.19549 R Squared .03822 S.E. of Est .54563 Sig. .0000
Intercept(S.E.) 1.10693(.06116) Slope(S.E.) -.85806(.09061)

9.4 Module 3 - Contractor's analysis

Using the performance indicators as described in chapter 6, it is possible to measure the bidding performance of any contractors in the database. For the purpose of demonstrating the output of this module, the bidding performance of one contractor is analysed and the results are shown below.

9.4.1 Bidding performance of contractor A

The bidding performance of contractor A for 1984 to 1989 is shown in tables 9.28 and 9.29. As illustrated in table 9.28, contractor A has submitted a total of 567 bids over the last six years (1984 to 1989) and has been successful on 147 contracts. The success rate of the company for the six year period is about 25.9% (147*100/567=25.9%). This means that on the average the firm has won one job out of every four contract bids submitted by the firm.

As shown in table 9.28, the tender success rate of the firm varies from 0% in 1989 (only 11 cases are recorded) to 30.4% in 1984. Although the success rate of the firm is maintained at about 25% in all the years, the average win margin has gradually increased since 1984 (from 4.6% to 9.9%). This implies that the firm has been leaving more "money on the table" in recent years and thus reflects upon the general decline in bidding efficiency of the firm in competitive bidding.

The tender success value of the firm as shown in table 9.29 ranges from 1 : 2.9 (1984) to 1 : 5.4 (1985). The overall tender success value for 1984 to 1989 is 1 : 4.2 (£103m divided by £428m). This indicates that contractor A has managed to secure one pound worth of contract out of every four pounds of contract tendered by the firm.

A comparison of tender success value among different years shows that the contractor had been more successful in 1984 than other years. This performance is further confirmed by

Table 9.28 : Bidding performance of contractor A

YEAR	TOTAL NO. OF BIDS SUBMITTED	NO. OF SUCCESSFUL BIDS	SUCCESS RATE (%)	AVERAGE WIN MARGIN (%)	AVERAGE LOSE MARGIN (%)
1984	92	28	30.4	4.6	-9.4
1985	135	35	25.9	5.7	-10.1
1986	107	26	24.3	5.8	-9.8
1987	179	48	26.8	7.5	-11.0
1988	43	10	23.26	9.9	-12.3
1989	11	0	0	-	-13.4

a) Total number of bids submitted (1984-1989) = 567
b) Total number of successful bids = 147
c) Tender success rate = 25.9%

Table 9.29 : Tender success value of contractor A

YEAR	TOTAL VALUE OF CONTRACTS TENDERED (£m)	TOTAL VALUE OF CONTRACTS WON (£m)	TENDER SUCCESS VALUE
1984	57.8	20.2	1 : 2.9
1985	95.4	22.8	1 : 4.2
1986	89.5	16.6	1 : 5.4
1987	144.3	36.1	1 : 4.0
1988	31.0	7.3	1 : 4.3
1989	9.8	0	0

a) Total value of contracts tendered (1984-1989) = 428 million pounds
b) Total value of contracts won = 103 million pounds
c) Tender success value = 1 : 4.2

the high success rate of 30.4% and a relatively small win margin of 4.6%. Thus, the above measures clearly indicate that contractor A was relatively more efficient and successful in 1984 than other years.

Therefore, the measurement of tender success rate, tender success value and the win/lose margin provides useful feedback information to contractors in monitoring their bidding performance in competitive bidding. In also enables contractors to adopt any corrective actions to improve the efficiency and effectiveness of their existing bidding strategies when necessary.

9.4.2 Win margin distribution of contractor A

As displayed in figure 9.18, the win margin distribution of contractor A is positively skewed. The mean win margin is 6.3% and has a standard deviation of 6.9. The win margin ranges from a minimum of 0.1% to a maximum of 43.6% and has a median of 4.7%. The median indicates that 50% of contractor A's bids were secured with win margin of 4.7% or more.

The mean bid spread (win margin) of all refurbishment contracts is 6.2% as shown in figure 9.8. Using this value as a yardstick (general standard of the industry) for measuring bidding performance of contractors, the mean win margin (6.3%) of contractor A is only slightly higher. Thus, we may consider contractor A's bidding performance as satisfactory. However, as indicated by the median win margin, there is still more scope for increasing the bidding efficiency of the firm.

9.4.3 Lose margin distribution of contractor A

The lose margin distribution of contractor A is negatively skewed as displayed in figure 9.19. The lose margin ranges from 0.1% to 45.2% and has a mean of 10.5%. This shows that on the average, contractor A's unsuccessful bids are approximately 10% higher than

Figure 9.18 : Win margin distribution of Contractor A

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY  1.00 OCCURRENCE

    0      -3.0
   19       -.5  *******************
   41       2.0  *****************************************
   30       4.5  ******************************
   21       7.0  *********************
   12       9.5  ************
    6      12.0  ******
    8      14.5  ********
    5      17.0  *****
    0      19.5
    1      22.0  *
    0      24.5
    1      27.0  *
    0      29.5
    0      32.0
    0      34.5
    2      37.0  **
    0      39.5
    0      42.0
    1      44.5  *
    0      47.0
                 I....+....I....+....I....+....I....+....I....+....I
                 0        10        20        30        40        50
                           HISTOGRAM FREQUENCY

MEAN          6.285     STD ERR       .566     MEDIAN       4.596
MODE          1.434     STD DEV      6.859     VARIANCE    47.048
KURTOSIS      9.726     S E KURT      .397     SKEWNESS     2.867
S E SKEW       .200     RANGE       43.816     MINIMUM       .000
MAXIMUM      43.816     SUM        923.884

VALID CASES     147     MISSING CASES    0
```

the lowest bidder. It is also observed from the distribution that there are 92 (67+25 = 92 as shown in figure 9.19) contracts which contractor A had lost by a margin of between 0% to 2.5%. This implies that if contractor had reduced all his bids by 2.5%, he would have secured another 92 contracts. But, this would also increase the win margin of his successful contracts.

Based upon the distribution of unsuccessful bids and their respective lose margins as shown in figure 9.19, it is observed that contractor A had been very competitive in refurbishment work as a large proportion of his bids are lost at competitive margins. Thus, the lose margin provides an useful measure for monitoring the competitiveness of a contractor's bids.

Figure 9.19 : Lose margin distribution of Contractor A

```
COUNT   MIDPOINT   ONE SYMBOL EQUALS APPROXIMATELY  1.60 OCCURRENCES

    0     -47.5
    1     -45.0  *
    0     -42.5
    1     -40.0  *
    1     -37.5  *
    2     -35.0  *
    3     -32.5  **
    3     -30.0  **
    9     -27.5  ******
    9     -25.0  ******
   20     -22.5  *************
   20     -20.0  *************
   24     -17.5  ***************
   27     -15.0  *****************
   33     -12.5  *********************
   49     -10.0  *******************************
   69      -7.5  *******************************************
   57      -5.0  ************************************
   67      -2.5  ******************************************
   25        .0  ****************
    0       2.5
                 I....+....I....+....I....+....I....+....I....+....I
                 0        15        30        45        60        75
                           HISTOGRAM FREQUENCY

MEAN        -10.469    STD ERR        .388    MEDIAN      -8.461
MODE         -5.677    STD DEV       7.950    VARIANCE    63.196
KURTOSIS      1.194    S E KURT       .238    SKEWNESS    -1.117
S E SKEW       .119    RANGE        45.188    MINIMUM    -45.327
MAXIMUM       -.140    SUM       -4396.794

VALID CASES     420     MISSING CASES     0
```

9.4.4 Contractor's bid to mean bid ratio

The contractor's bid to mean bid ratio of contractor A is displayed in figure 9.20. As observed in the figure, the contractor's bid to mean bid ration is approximately normally distributed. The mean ratio is 99.2% and has a standard deviation of 7.6. It ranges from a minimum of 74.0% to 137.1%. This result indicates that contractor's A bids are quite competitive as his bids are close to the bid mean of all bids in a contract.

9.4.5 Identification of strengths and weaknesses of contractor A

Table 9.30 displays a typical output from the decision support system showing a listing of all past contracts of contractor A. The listing provides details on the job characteristics and the bidding performance (win/lose margin) of the contractor. Thus, by analysing

Figure 9.20 : Contractor's bid to mean bid ratio distribution

```
CONTRACTOR'S BID TO MEAN BID RATIO

   COUNT    MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY  4.00 OCCURRENCES

       1       72.33
       3       75.67  *
       4       79.00  *
       7       82.33  **
      14       85.67  ****
      26       89.00  ******
      63       92.33  ****************
     120       95.67  ******************************
     108       99.00  ***************************
      87      102.33  **********************
      59      105.67  ***************
      37      109.00  *********
      25      112.33  ******
       8      115.67  **
       3      119.00  *
       0      122.33
       0      125.67
       0      129.00
       0      132.33
       2      135.67  *
       0      139.00
                      I....+....I....+....I....+....I....+....I....+....I
                      0        40        80       120       160       200
                                     HISTOGRAM FREQUENCY

MEAN            99.162    STD ERR          .317    MEDIAN        98.809
MODE            96.098    STD DEV         7.556    VARIANCE      57.098
KURTOSIS         2.219    S E KURT         .206    SKEWNESS        .295
S E SKEW          .103    RANGE          63.113    MINIMUM       73.996
MAXIMUM        137.109    SUM         56224.703

VALID CASES        567    MISSING CASES  1694
```

tender bid records of past contracts, contractors will be able to understand and monitor the bidding performance of their firms under various bidding situations.

Besides this, module 3 also provides a listing of past contracts in specific bidding situations such as different job types or job sizes. Table 9.31 shows an example of the decision support system's output on the past bidding performance of contractor A for various job types. Thus, by monitoring the bidding performance of the company for various bidding situations, the contractor will be able to formulate appropriate strategies for various bidding situations. For example, if the above analysis shows that contractor A had not been very successful in certain job types, appropriate actions may be taken to improve the competitive position of the firm in the industry.

Table 9.30 : Computer output of past contracts of Contractor A

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
9501	2	5	1	2	8	4	21	237	120	4	1	0	0	0	0	0	17.75
7961	2	4	1	1	3	4	339	138	21	462	0	0	0	0	0	0	-24.37
9391	2	5	1	2	7	4	9	155	21	19	7	0	0	0	0	0	-2.81
8461	2	3	1	1	1	4	21	120	418	0	0	0	0	0	0	0	8.96
7781	2	5	1	1	3	4	25	27	21	215	247	0	0	0	0	0	-2.81
8641	2	4	2	1	3	4	19	21	3	317	0	0	0	0	0	0	-3.75
7521	2	3	2	2	5	4	31	418	21	0	0	0	0	0	0	0	-9.85
5741	2	4	2	1	8	4	28	384	8	21	0	0	0	0	0	0	-23.37
9471	2	4	2	1	3	4	253	28	322	21	0	0	0	0	0	0	-15.82
7031	2	4	2	1	8	4	84	106	21	83	0	0	0	0	0	0	-11.46
9231	2	3	2	1	3	4	28	321	21	0	0	0	0	0	0	0	-24.30
9151	2	4	2	2	3	4	2	95	463	21	0	0	0	0	0	0	-28.61
9201	2	3	2	2	8	4	321	21	9	0	0	0	0	0	0	0	-8.31
8301	2	4	2	2	3	4	21	369	244	22	0	0	0	0	0	0	1.93
8421	2	3	2	1	1	4	364	21	449	0	0	0	0	0	0	0	-9.43
8911	2	3	2	2	3	4	21	177	198	0	0	0	0	0	0	0	2.27
9121	2	4	2	2	1	4	422	21	131	19	0	0	0	0	0	0	-2.19
6321	2	3	2	2	3	4	19	16	21	0	0	0	0	0	0	0	-11.86
5651	2	5	2	1	7	4	83	21	9	151	1	0	0	0	0	0	-4.58
9131	2	4	2	1	8	4	192	157	47	21	0	0	0	0	0	0	-16.56
5991	2	4	2	2	8	4	321	9	192	21	0	0	0	0	0	0	-20.33
7551	2	3	2	2	3	4	5	21	167	0	0	0	0	0	0	0	-1.11
7751	2	6	2	1	8	4	268	227	35	12	131	21	0	0	0	0	-34.05
5541	2	3	2	1	3	4	5	384	21	0	0	0	0	0	0	0	-8.38
8491	2	5	3	2	1	4	21	9	372	28	418	0	0	0	0	0	2.57
6691	2	5	3	2	8	4	119	10	21	423	19	0	0	0	0	0	-9.31
6271	2	6	3	1	4	4	5	66	21	369	14	23	0	0	0	0	-1.08
7941	2	3	3	2	4	4	35	391	21	0	0	0	0	0	0	0	-11.42
6741	2	3	3	1	8	4	21	1	244	0	0	0	0	0	0	0	.42
9681	2	4	3	2	3	4	237	29	21	28	0	0	0	0	0	0	-7.73
6931	2	5	3	1	3	4	248	7	22	8	21	0	0	0	0	0	-5.75
9371	2	5	3	1	3	4	21	31	2	348	19	0	0	0	0	0	.02
9251	2	5	3	1	4	4	541	21	143	25	20	0	0	0	0	0	-2.04
7061	2	5	3	1	3	4	167	240	227	21	9	0	0	0	0	0	-12.62
9591	2	6	3	1	1	5	35	25	170	320	21	20	0	0	0	0	-15.38
7001	2	5	3	2	8	4	457	116	17	392	21	0	0	0	0	0	-23.93
7681	2	6	3	2	3	4	30	294	21	164	325	20	0	0	0	0	-6.42
8981	2	3	3	1	3	4	423	429	21	0	0	0	0	0	0	0	-7.22
8761	2	6	3	2	3	4	18	367	136	21	418	4	0	0	0	0	-5.28
9701	2	6	3	1	3	5	470	319	21	469	419	91	0	0	0	0	-4.52
7821	2	8	3	2	8	4	18	354	154	33	30	21	231	143	0	0	-13.56
7691	2	9	3	1	8	4	414	21	8	288	389	28	35	143	458	0	-.51
8871	2	4	3	2	7	4	1	10	108	21	0	0	0	0	0	0	-9.07
6631	2	4	3	1	3	4	21	251	322	34	0	0	0	0	0	0	10.31
5581	2	5	3	2	3	4	214	21	4	19	7	0	0	0	0	0	-1.51

Table 9.31 : Computer output of past contracts of Contractor A for different job type

Job type 1 (Transport and utility)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
8461	2	3	1	1	1	4	21	120	418	0	0	0	0	0	0	0	8.96
8421	2	3	2	1	1	4	364	21	449	0	0	0	0	0	0	0	-9.43
9121	2	4	2	2	1	4	422	21	131	19	0	0	0	0	0	0	-2.19
8491	2	5	3	2	1	4	21	9	372	28	418	0	0	0	0	0	2.57
9591	2	6	3	1	1	5	35	25	170	320	21	20	0	0	0	0	-15.38
7831	2	6	4	1	1	5	125	14	21	20	25	320	0	0	0	0	-8.73
371	3	3	5	2	1	4	28	215	21	0	0	0	0	0	0	0	-3.33
3971	3	4	3	2	1	5	21	1	25	14	0	0	0	0	0	0	5.24
4711	3	5	3	1	1	4	20	198	21	196	215	0	0	0	0	0	-10.69
9831	3	6	14	1	1	4	8	198	21	26	215	20	0	0	0	0	-4.08
760	4	3	3	2	1	4	1	19	21	0	0	0	0	0	0	0	-16.92
3868	4	4	3	2	1	4	198	5	29	21	0	0	0	0	0	0	-7.83
2251	5	7	3	1	1	5	237	391	4	21	17	131	23	0	0	0	-9.58
3813	5	4	3	1	1	4	772	230	21	773	0	0	0	0	0	0	-13.36
4063	5	4	1	2	1	4	104	202	21	611	0	0	0	0	0	0	-16.74
4495	5	5	1	2	1	4	17	722	21	419	322	0	0	0	0	0	-33.03
4893	5	3	2	1	1	4	276	21	253	0	0	0	0	0	0	0	-.14
8354	6	4	4	2	1	4	21	823	929	912	0	0	0	0	0	0	6.39
9032	6	5	4	2	1	5	960	234	11	823	21	0	0	0	0	0	-18.34

Job type 2 (Industrial)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
2311	3	3	8	2	2	4	1	31	21	0	0	0	0	0	0	0	-2.07
2441	3	3	1	1	2	4	348	21	33	0	0	0	0	0	0	0	-1.27
41	3	3	3	1	2	4	242	20	21	0	0	0	0	0	0	0	-2.09
9801	3	5	3	2	2	5	21	519	294	33	10	0	0	0	0	0	13.21
1138	4	3	3	1	2	4	27	21	4	0	0	0	0	0	0	0	-4.28
687	4	6	3	1	2	4	244	10	320	21	152	340	0	0	0	0	-3.82
2932	4	8	4	1	2	4	9	19	21	32	1	214	30	244	0	0	-3.78
2932	4	8	4	1	2	4	9	19	21	32	1	214	30	244	0	0	-3.78
1716	5	6	4	1	2	4	575	576	524	30	21	19	0	0	0	0	-19.41
4718	5	4	3	2	2	4	21	40	93	248	0	0	0	0	0	0	6.24
7697	6	5	3	1	2	5	21	215	823	8	880	0	0	0	0	0	7.75
7685	6	5	3	2	2	4	21	6	999	19	581	0	0	0	0	0	10.77
9023	6	3	4	2	2	4	906	21	524	0	0	0	0	0	0	0	-9.30
9161	6	3	3	2	2	4	833	912	21	0	0	0	0	0	0	0	-8.19
3012	7	5	3	1	2	4	27	872	21	93	237	0	0	0	0	0	-23.00

Job type 3 (Administration, public & office)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
7961	2	4	1	1	3	4	339	138	21	462	0	0	0	0	0	0	-24.37
7781	2	5	1	1	3	4	25	27	21	215	247	0	0	0	0	0	-2.81
8641	2	4	2	1	3	4	19	21	3	317	0	0	0	0	0	0	-3.75
9471	2	4	2	1	3	4	253	28	322	21	0	0	0	0	0	0	-15.82
9231	2	3	2	1	3	4	28	321	21	0	0	0	0	0	0	0	-24.30
9151	2	4	2	2	3	4	2	95	463	21	0	0	0	0	0	0	-28.61
8301	2	4	2	2	3	4	21	369	244	22	0	0	0	0	0	0	1.93
8911	2	3	2	2	3	4	21	177	198	0	0	0	0	0	0	0	2.27
6321	2	3	2	2	3	4	19	16	21	0	0	0	0	0	0	0	-11.86
7551	2	3	2	2	3	4	5	21	167	0	0	0	0	0	0	0	-1.11
5541	2	3	2	1	3	4	5	384	21	0	0	0	0	0	0	0	-8.38
9681	2	4	3	2	3	4	237	29	21	28	0	0	0	0	0	0	-7.73
6931	2	5	3	1	3	4	248	7	22	8	21	0	0	0	0	0	-5.75
9371	2	5	3	1	3	4	21	31	2	348	19	0	0	0	0	0	.02
7061	2	5	3	1	3	4	167	240	227	21	9	0	0	0	0	0	-12.62
7681	2	6	3	2	3	4	30	294	21	164	325	20	0	0	0	0	-6.42
8981	2	3	3	1	3	4	423	429	21	0	0	0	0	0	0	0	-7.22
8761	2	6	3	2	3	4	18	367	136	21	418	4	0	0	0	0	-5.28
9701	2	6	3	1	3	5	470	319	21	469	419	91	0	0	0	0	-4.52
6631	2	4	3	1	3	4	21	251	322	34	0	0	0	0	0	0	10.31
5581	2	5	3	2	3	4	214	21	4	19	7	0	0	0	0	0	-1.51
8241	2	6	3	2	3	4	21	515	27	242	22	516	0	0	0	0	16.57
8471	2	7	3	1	3	4	21	9	211	19	248	3	120	0	0	0	.01
7461	2	5	3	2	3	4	30	155	21	33	20	0	0	0	0	0	-3.08
7641	2	5	4	2	3	4	21	9	426	214	136	0	0	0	0	0	.42
8111	2	6	4	2	3	4	19	10	21	31	33	512	0	0	0	0	-2.16
6911	2	8	4	1	3	4	103	21	215	320	25	30	23	418	0	0	-5.70

Job type 4 (Health & welfare)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
6271	2	6	3	1	4	4	5	66	21	369	14	23	0	0	0	0	-1.08
7941	2	3	3	2	4	4	35	391	21	0	0	0	0	0	0	0	-11.42
9251	2	5	3	1	4	4	541	21	143	25	20	0	0	0	0	0	-2.04
7151	2	4	3	2	4	4	21	215	20	6	0	0	0	0	0	0	6.48
7161	2	5	4	2	4	4	21	215	20	6	244	0	0	0	0	0	7.12
6391	2	3	7	1	4	4	21	391	215	0	0	0	0	0	0	0	3.00
2591	3	3	1	1	4	4	21	210	33	0	0	0	0	0	0	0	10.56
3171	3	3	1	1	4	4	340	279	21	0	0	0	0	0	0	0	-19.08
3181	3	3	1	1	4	4	21	340	279	0	0	0	0	0	0	0	10.15
221	3	4	10	1	4	4	21	391	2	33	0	0	0	0	0	0	3.76
4041	3	4	2	1	4	4	33	2	131	21	0	0	0	0	0	0	-15.03
531	3	5	3	1	4	4	21	348	91	95	31	0	0	0	0	0	.00
3451	3	5	2	1	4	4	9	391	348	131	21	0	0	0	0	0	-22.84
1491	3	6	2	1	4	4	21	2	31	66	340	421	0	0	0	0	1.09
1871	3	6	1	1	4	4	1	108	143	21	7	320	0	0	0	0	-16.98
3841	3	6	1	1	4	4	108	7	1	21	320	143	0	0	0	0	-11.93
2831	3	6	3	1	4	4	25	29	102	21	23	33	0	0	0	0	-3.81
4544	4	4	2	1	4	4	21	66	23	5	0	0	0	0	0	0	.73
1410	4	5	2	1	4	5	21	28	14	5	143	0	0	0	0	0	.29
2009	4	5	5	1	4	4	66	198	9	1	21	0	0	0	0	0	-7.43
2383	4	6	4	1	4	4	36	21	28	418	31	17	0	0	0	0	-2.65
2367	4	6	6	1	4	5	420	35	17	198	320	21	0	0	0	0	-10.59

Job type 5 (Refreshment, recreation & entertainment)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
7521	2	3	2	2	5	4	31	418	21	0	0	0	0	0	0	0	-9.85
1601	3	3	3	1	5	4	293	21	198	0	0	0	0	0	0	0	-6.45
3131	3	4	2	1	5	4	207	95	86	21	0	0	0	0	0	0	-9.69
381	3	4	2	1	5	4	21	73	179	35	0	0	0	0	0	0	9.17
4451	3	5	4	1	5	4	21	23	131	27	106	0	0	0	0	0	1.50
9781	3	7	6	1	5	4	21	10	418	215	2	143	427	0	0	0	2.08
3152	4	3	4	2	5	5	30	14	21	0	0	0	0	0	0	0	-6.34
1451	4	4	2	2	5	4	21	3	4	131	0	0	0	0	0	0	1.79
512	4	6	4	1	5	4	21	215	2	30	35	31	0	0	0	0	1.92
3977	4	6	2	1	5	4	290	21	348	131	244	22	0	0	0	0	-.38
131	5	4	4	2	5	5	17	21	198	19	0	0	0	0	0	0	-6.81
2053	5	4	1	1	5	5	399	21	288	5	0	0	0	0	0	0	-.71
572	5	4	5	2	5	4	5	29	21	30	0	0	0	0	0	0	-10.08
644	5	6	4	2	5	4	294	30	21	19	28	29	0	0	0	0	-7.18
763	5	6	3	2	5	5	17	19	21	327	241	27	0	0	0	0	-5.68
763	5	6	3	2	5	4	17	19	21	327	241	27	0	0	0	0	-5.68
3669	5	4	7	2	5	4	19	21	13	1	0	0	0	0	0	0	-18.93
4493	5	3	2	2	5	4	541	322	21	0	0	0	0	0	0	0	-19.32
4517	5	6	6	2	5	4	40	416	21	727	33	316	0	0	0	0	-8.52
4676	5	5	5	2	5	4	51	79	418	21	30	0	0	0	0	0	-7.28
4923	5	4	3	2	5	4	391	33	21	131	0	0	0	0	0	0	-6.50
5366	5	4	3	1	5	4	21	25	490	805	0	0	0	0	0	0	14.47

Job type 6 (Religious)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
781	3	3	5	2	6	4	21	1	35	0	0	0	0	0	0	0	5.52
1267	4	5	3	2	6	4	21	33	103	66	321	0	0	0	0	0	2.21
24	5	3	3	1	6	4	21	369	4	0	0	0	0	0	0	0	5.35
229	5	4	1	2	6	4	391	21	7	103	0	0	0	0	0	0	-1.67
682	5	6	4	2	6	4	21	1	19	532	131	9	0	0	0	0	7.41
4077	5	5	2	2	6	4	391	250	336	318	21	0	0	0	0	0	-20.42
7763	6	5	3	2	6	4	828	608	21	380	320	0	0	0	0	0	-31.55

Job type 7 (Education, information & scientific)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
9391	2	5	1	2	7	4	9	155	21	19	7	0	0	0	0	0	-2.81
5651	2	5	2	1	7	4	83	21	9	151	1	0	0	0	0	0	-4.58
8871	2	4	3	2	7	4	1	10	108	21	0	0	0	0	0	0	-9.07
7391	2	8	3	1	7	4	131	214	320	248	143	21	193	115	0	0	-3.15
6111	2	4	3	2	7	4	21	155	7	9	0	0	0	0	0	0	1.43
5981	2	4	3	2	7	4	21	155	7	9	0	0	0	0	0	0	1.43
2721	3	4	2	1	7	4	21	360	420	252	0	0	0	0	0	0	4.97
2571	3	4	2	1	7	4	237	155	1	21	0	0	0	0	0	0	-9.65
3401	3	4	2	1	7	4	21	153	16	31	0	0	0	0	0	0	1.28
3481	3	6	2	1	7	4	21	104	28	10	244	271	0	0	0	0	6.19
3961	3	6	2	2	7	4	1	21	8	2	9	31	0	0	0	0	-.77
321	3	6	3	1	7	4	365	120	21	28	23	10	0	0	0	0	-7.18
2681	3	6	2	2	7	4	147	115	365	21	23	197	0	0	0	0	-7.21
1851	3	6	2	1	7	4	206	28	337	21	105	214	0	0	0	0	-8.28
331	3	6	3	1	7	4	198	27	17	21	19	30	0	0	0	0	-1.88
2821	3	6	3	1	7	4	143	175	21	424	410	14	0	0	0	0	-5.88
2461	3	6	2	1	7	4	17	198	21	25	27	23	0	0	0	0	-10.44
4071	3	7	3	1	7	4	260	4	21	320	418	247	108	0	0	0	-4.62
871	3	8	3	1	7	4	143	409	16	391	10	21	320	23	0	0	-16.76
1791	3	8	5	1	7	4	79	320	402	143	418	378	21	135	0	0	-11.20
1921	3	9	4	1	7	4	206	61	105	214	190	28	21	418	19	0	-23.03
4767	4	4	2	1	7	5	19	21	131	423	0	0	0	0	0	0	-.37

Job type 8 (Residential)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	MARGIN
9501	2	5	1	2	8	4	21	237	120	4	1	0	0	0	0	0	17.75
5741	2	4	2	1	8	4	28	384	8	21	0	0	0	0	0	0	-23.37
7031	2	4	2	1	8	4	84	106	21	83	0	0	0	0	0	0	-11.46
9201	2	3	2	2	8	4	321	21	9	0	0	0	0	0	0	0	-8.31
9131	2	4	2	1	8	4	192	157	47	21	0	0	0	0	0	0	-16.56
5991	2	4	2	2	8	4	321	9	192	21	0	0	0	0	0	0	-20.33
7751	2	6	2	1	8	4	268	227	35	12	131	21	0	0	0	0	-34.05
6691	2	5	3	2	8	4	119	10	21	423	19	0	0	0	0	0	-9.31
6741	2	3	3	1	8	4	21	1	244	0	0	0	0	0	0	0	.42
7001	2	5	3	2	8	4	457	116	17	392	21	0	0	0	0	0	-23.93
7821	2	8	3	2	8	4	18	354	154	33	30	21	231	143	0	0	-13.56
7691	2	9	3	1	8	4	414	21	8	288	389	28	35	143	458	0	-.51
6161	2	3	3	1	8	4	260	21	404	0	0	0	0	0	0	0	-10.11
8741	2	5	4	2	8	4	457	260	9	21	86	0	0	0	0	0	-4.13
9181	2	6	4	1	8	4	21	384	409	33	337	237	0	0	0	0	2.33
6681	2	6	4	2	8	4	4	21	215	280	244	131	0	0	0	0	-7.44
6381	2	6	5	1	8	4	391	5	21	31	28	143	0	0	0	0	-6.37
9341	2	3	5	2	8	4	21	152	131	0	0	0	0	0	0	0	3.60
5811	2	6	5	1	8	4	305	136	205	21	157	193	0	0	0	0	-17.69
8711	2	4	5	1	8	4	2	21	28	251	0	0	0	0	0	0	-3.01
6061	2	3	5	1	8	4	21	8	33	0	0	0	0	0	0	0	8.37
8721	2	6	5	1	8	4	2	131	21	414	28	251	0	0	0	0	-4.80
8011	2	6	5	1	8	4	136	389	131	30	21	418	0	0	0	0	-16.48
8181	2	5	5	1	8	4	21	12	120	9	6	0	0	0	0	0	7.41
6081	2	3	5	1	8	4	21	8	33	0	0	0	0	0	0	0	10.45

9.5 Module 4 - Competitors' analysis

The main purpose of this module is to provide information which will enable a contractor to monitor the bidding performance of his firm against his competitors, particularly his key competitors (contractors whom he frequently meets). For the purpose of demonstrating the output of the decision support information produced by this module, we analyse the bidding performance of one contractor (contractor A) against 10 of his key competitors (K1 to K10).

9.5.1 Bidding performance of contractor A against his key competitors

Table 9.32 shows the bidding performance of contractor A against 10 of his frequently encountered competitors in refurbishment work. The key competitors are listed in descending order according to the frequency of encounters. As observed in table 9.32, the success rate of contractor A against his key competitors ranges between 37.7% (K2) to 80.0% (K9). The measurement of success rate determines the competition power between contractor A and his respective competitors. Thus, the above results show that contractor A has relatively high competitive strength against most of his key competitors (success rate over 50%) except K2, K7 and K10.

From table 9.32, it is observed that the mean win margin of contractor A against his key competitors is quite large (about 9% to 10%) except for competitors K3 and K8. This clearly shows that contractor A's bids are much more competitive than his key competitors. Comparing the lose margin of contractor A against his key competitors, it is observed that contractor A tends to lose by a larger margin to competitors K2 (9.9%) and K3 (8.1%). Thus, the analysis of relative bidding performance between a contractor and his key competitors provides essential feedback information to contractors. It also enables a contractor to have a better understanding of the bidding behaviour of his key competitors.

Table 9.32 : Bidding performance of Contractor A against his key competitors

KEY COMPETITORS	TOTAL NO. OF ENCOUNTERS	NUMBER OF BIDS WON BY CONTRACTOR A	SUCCESS RATE (%)	AVERAGE WIN MARGIN (%)	AVERAGE LOSE MARGIN (%)
K1	70	38	54.3	9.9	-7.8
K2	61	23	37.7	12.5	-9.9
K3	60	33	55.0	7.2	-8.1
K4	59	39	66.1	10.5	-5.4
K5	58	33	56.9	10.6	-3.9
K6	58	34	58.6	10.8	-7.8
K7	52	23	44.2	9.3	-7.7
K8	47	28	59.6	8.0	-7.8
K9	45	36	80.0	8.7	-7.1
K10	36	14	38.9	10.4	-5.8

9.5.2 Identification of strengths and weaknesses of competitors

Table 9.33 displays a computer output showing the job characteristics, coded identities of bidders and win/lose margin of past contracts where contractor A and his key competitor K4 were in competition. The list of past contracts in divided into two parts. The first listing provides a list of contracts where contractor A's bids were lower than his key competitor K4. While the second listing displays contracts where contractor A's bids are higher than competitor K4. Both the listings show the extent of margin (win/lose margin) by which contractor A has won or lost in all the contracts. Thus, by relating the relative bidding performance between a contractor and his key competitors under different contract characteristics, the contractor will be able to identify the strengths and weaknesses of his competitors. For instance, contractor A may find that key competitor K4 had been consistently submitting lower bids than his firm for residential or office buildings. As such, he may take appropriate actions to improve his competitive power against competitor K4.

Table 9.33 : Computer output of past contracts of Contractor A against his key competitor (K4)

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	WIN4
9121	2	4	2	2	1	4	422	21	131	19	0	0	0	0	0	0	32.01
6681	2	6	4	2	8	4	4	21	215	280	244	131	0	0	0	0	13.78
9341	2	3	5	2	8	4	21	152	131	0	0	0	0	0	0	0	10.28
3001	3	4	2	2	3	4	22	21	131	369	0	0	0	0	0	0	1.09
3941	3	4	3	1	8	4	21	131	120	106	0	0	0	0	0	0	4.97
4451	3	5	4	1	5	4	21	23	131	27	106	0	0	0	0	0	1.70
3431	3	5	4	1	8	4	398	28	21	131	179	0	0	0	0	0	6.54
4141	3	6	8	1	8	4	420	21	30	8	131	392	0	0	0	0	4.39
1881	3	6	11	2	8	4	391	9	30	260	21	131	0	0	0	0	3.03
911	3	6	2	1	3	4	21	369	131	423	215	34	0	0	0	0	2.37
4361	3	6	9	1	8	4	21	9	15	214	320	131	0	0	0	0	11.03
1051	3	6	5	1	8	4	21	253	152	131	2	25	0	0	0	0	10.19
4101	3	6	5	1	8	4	21	25	131	414	418	120	0	0	0	0	17.12
4721	3	8	3	2	3	4	21	8	2	320	288	31	131	19	0	0	13.26
4739	4	3	2	1	8	4	21	17	131	0	0	0	0	0	0	0	14.06
4767	4	4	2	1	7	5	19	21	131	423	0	0	0	0	0	0	11.72
136	4	4	7	1	8	4	21	33	131	5	0	0	0	0	0	0	10.52
1451	4	4	2	2	5	4	21	3	4	131	0	0	0	0	0	0	12.26
2568	4	5	3	1	8	5	12	21	240	198	131	0	0	0	0	0	13.26
2773	4	5	4	1	8	4	533	33	21	131	6	0	0	0	0	0	1.76
4827	4	6	5	1	8	4	84	256	533	21	131	1	0	0	0	0	3.44
3977	4	6	2	1	5	4	290	21	348	131	244	22	0	0	0	0	9.63
3112	4	6	3	1	3	4	27	5	21	131	23	425	0	0	0	0	1.29

JOBNO	YEAR	NOBID	JOBSIZE	CLIENT	JOBTYPE	LOCATION	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	LOSE4
7751	2	6	2	1	8	4	268	227	35	12	131	21	0	0	0	0	.28
7391	2	8	3	1	7	4	131	214	320	248	143	21	193	115	0	0	3.15
8721	2	6	5	1	8	4	2	131	21	414	28	251	0	0	0	0	2.49
8011	2	6	5	1	8	4	136	389	131	30	21	418	0	0	0	0	4.64
6451	2	5	6	1	3	4	214	192	131	21	244	0	0	0	0	0	1.96
4281	3	4	3	1	8	4	220	131	33	21	0	0	0	0	0	0	13.90
4041	3	4	2	1	4	4	33	2	131	21	0	0	0	0	0	0	6.74
3451	3	5	2	1	4	4	9	391	348	131	21	0	0	0	0	0	2.44
471	3	6	3	1	8	4	35	391	131	244	21	136	0	0	0	0	9.35
4736	4	3	5	2	8	4	9	131	21	0	0	0	0	0	0	0	.49
2155	4	5	4	1	8	4	253	6	131	21	235	0	0	0	0	0	.53
4244	4	7	2	1	8	4	391	131	384	21	7	15	13	0	0	0	7.36
4260	4	7	6	2	8	4	131	136	21	418	30	18	423	0	0	0	.86
341	5	4	6	1	8	4	131	30	21	32	0	0	0	0	0	0	16.20
341	5	4	6	1	8	4	131	30	21	32	0	0	0	0	0	0	16.21
951	5	5	6	1	8	4	524	131	15	6	21	0	0	0	^	0	10.70
463	5	6	3	1	8	4	268	360	131	21	259	240	0	0		0	.79
596	5	8	3	1	3	4	391	131	21	1	7	364	15	143	0	0	2.49
3273	5	6	4	2	8	4	202	354	131	21	143	674	0	0	0	0	5.53
4974	5	9	5	2	8	4	410	391	202	8	420	131	21	524	310	0	2.18

0

Number of cases read! 20 Number of cases listed! 20

9.5.3 Identification of specialities of competitors in refurbishment work

Tables 9.34 and 9.35 display a list of 30 refurbishment contractors who were frequent lowest bidders under various job characteristic bidding conditions. From the tables, it is possible to identify the specialities and interests of various contractors (most competitive bidders for various conditions). For example, as illustrated in table 9.34 contractors C001 and C007 are very competitive bidders for jobs ranging between job sizes 1 to 11, as indicated by the high frequency of successful bids. Both companies are keen on public and private jobs. However, contractor C007 tends to be more selective in his job types (job types 4, 6, and 8) while C001 seems to be competitive in all job types.

Thus, the information as displayed in table 9.34 enables contractors to understand which competing contractors will be keen to tender for various job sizes, job types, client types and job locations. Such information provides useful guidelines to management during tender adjudication, especially when the identities of other bidders are known. By understanding the speciality and interest of various bidders, contractors are better equipped to formulate suitable bidding strategies to increase the success rate of the company.

Thus, by simply analysing the frequency of lowest bids of various contractors, significant market information may be obtained at any point in time to identify the specialties and interests of the most competitive bidders under various bidding conditions.

Table 9.34 : Identification of speciality of contractors

(job size)

CONTRACTORS	JOB SIZE													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
C001	*	*	*	*	*	*	*	*	*	*				
C002	*			*				*						
C003	*	*		*									*	
C004	*													
C005	*													
C006		*	*											
C007		*	*	*	*	*	*	*		*	*			
C008		*	*											
C009			*											*
C010				*										
C011					*			*						
C012				*	*	*				*				*
C013					*									
C014					*									
C015						*								
C016						*								
C017							*							
C018										*				
C019											*			
C020												*		
C021									*					
C022									*					
C023									*					
C024														
C025														
C026														
C027														
C028														
C029														
C030														

(Note: * denotes that contractor has been frequent lowest bidder for that job size range.)

Table 9.35 : Identification of speciality of contractors

(job type, client type, and job location)

CONTRACTORS	JOB TYPE								CLIENT TYPE		JOB LOCATION	
	1	2	3	4	5	6	7	8	1	2	4	5
C001	*	*	*	*	*	*	*	*	*	*	*	*
C002		*	*			*				*	*	
C003	*				*				*			*
C004			*				*					
C005		*										
C006			*		*							
C007				*		*		*	*	*	*	*
C008			*	*								
C009								*				
C010	*	*					*		*		*	
C011	*		*									
C012			*		*					*	*	
C013								*				
C014												
C015							*					
C016			*				*					*
C017												
C018												
C019												
C020												
C021												
C022												
C023		*			*							*
C024	*											
C025	*								*		*	
C026	*											*
C027	*											
C028		*										
C029		*										
C030												*

(Note: * denotes that contractor has been frequent lowest bidder for the job type, client type or job location.)

9.6 Module 5 - Bidding models

9.6.1 Description of bidding models

This module aims to fit past tender bids of refurbishment contracts (lump sum contracts) into a Normal or Edgeworth distribution for the purpose of predicting (by means of order statistics) the distribution of the lowest bid of future contracts. Its prime objective is to provide a prediction model whereby contractors can determine the probability of success when submitting a tender bid in competitive bidding.

9.6.2 Research methodology adopted for bidding models

A total of 1350 refurbishment contracts during the period between 1984 and 1987 were analysed to determine the distributional characteristics of the tender bids. The tender bid records were collected through the Builders' Conference in London as described in chapter eight. All bids were indexed to the 1986 tender price level using the BCIS tender indices as shown in appendix B . The data were keyed into a specially formatted data file in the mainframe computer (DEC VAX 8700) at Heriot-Watt University. Statistical analyses of the data were performed using the SPSS-X statistical package. Besides this, a FORTRAN program was written by Dr W.F. Scott (co-supervisor of researcher) for computing the Normal and Edgeworth distribution of the tender bids as shown in appendix G .

Statistical tests of normality were conducted on the distribution of the tender bids. It was found that tender bids of refurbishment contracts may fit into either a Normal or Edgeworth distribution (which is slightly different from the Normal distribution). Hence, two tender bid prediction models were developed based upon these two distributions.

The Normal distribution model implies that both the true skewness and true kurtosis of tender bids are zero, even with varying true bid mean and variance. The Edgeworth distribution model includes skewness and kurtosis terms, and is therefore slightly more complicated. It is closely related to the normal distribution and arises from the Central Limit theorem. It has four parameters : (i) true mean, (ii) true standard deviation, (iii) true skewness and (iv) true kurtosis. The probability density curve of the standardised variable $\frac{X-\mu}{\sigma}$ is defined as follows:-

$$f(x) = \phi(x)\{1 + \frac{\gamma_1}{6}(x^3 - 3x) + \frac{\gamma_2}{24}(x^4 - 6x^2 + 3) + \frac{\gamma_1^2}{72}(x^6 - 15x^4 + 45x^2 - 15)\}$$

and it has a distribution function as follows:-

$$F(x) = \Phi(x) - \phi(x)\{\frac{\gamma_1}{6}(x^2 - 1) + \frac{\gamma_2}{24}(x^3 - 3x) + \frac{\gamma_1^2}{72}(x^5 - 10x^3 + 15x)\}$$

where $\phi(x) = \frac{e^{0.5x^2}}{\sqrt{2\pi}}$ (p.d.f. of the standard normal distribution)

In developing both the bidding models, various notations were adopted and these are listed as follows:-

g_1 : Sample skewness of tender bids per job.

g_2 : Sample kurtosis of tender bids per job.

γ_1 : True skewness of tender bids.

γ_2 : True kurtosis of tender bids.

μ : True mean of tender bids.

σ : True standard deviation of tender bids.

$\frac{\mu}{\sigma}$: Reciprocal of true coefficient of variation of bids.

n : Number of bidders against whom contractor is competing.

$\bar{x}$: Sample mean of tender bids per job.

N : Total number of cases for each bidding set (3,4,5....10 bidders).

c : Cost estimate of proposed job.

9.6.3 Assumptions of bidding models

A number of assumptions were made in the development of the models. These were as follows:-

a) There exists a true bid mean price for each contract and all bidders share the same opinion with regard to this price. The true coefficient of variation (and, for the Edgeworth model, skewness and kurtosis) also exists and is the same for all bidders.

b) The contractor knows the number of bidders against whom he is competing for the proposed contract.

c) It is possible to predict the estimated true bid mean of future contracts from the cost estimate of the job and the past tender bid records of the contractor. The ratios of cost estimate to bid mean of past contracts is used to estimate the true bid mean of future projects.

9.6.4 Parameters required for bidding models

There are several parameters which must be estimated in order to apply the prediction models. These parameters are partly derived from the past tender bid records of the contractors or other sources of information. They are listed as below:-

a) The number of bidders against whom the contractor is competing.
b) The true skewness and true kurtosis of tender bids (for Edgeworth model only).
c) The reciprocal of true coefficient of variation of tender bids.
d) The cost estimate of the proposed job.
e) The bid mean of the proposed job.

9.6.5 Development and testing of bidding models

The development and testing of the bidding models were carried out in three main stages. The principal activities involved in each stage are logically listed as follows:-

a) Step 1 - Determination of tender bid distribution.

i) Computation of sample skewness and kurtosis of tender bids.

ii) Testing for normality of tender bids (z-tests and Chi-square tests).

iii) Testing for independence of skewness and kurtosis with respect to the number of bidders and job type.

b) Step 2 - Fitting of Normal or Edgeworth distributions.

i) Determination of an unbiased estimator (R) for the reciprocal of true coefficient of variation of tender bids.

ii) Testing for independence of R with respect to the number of bidders, job type and bid mean.

iii) One-way analysis of variance of R by number of bidders, job type and bid mean.

iv) Two-way analysis of variance of R by number of bidders, job type and bid mean.

iv) Correlation and regression analysis of R.

c) Stage 3 - Testing of bidding models.

i) Testing of models on contractors A to E.

ii) Testing of reliability and accuracy of bid predictions.

9.6.5.1 Step 1 : Determination of tender bid distribution

9.6.5.1.1 Computation of sample skewness and kurtosis of tender bids

The first stage of the model development involved the determination of the tender bid distribution characteristics of the 1350 refurbishment contracts. Each refurbishment contract was considered as a random observation comprising a set of tender bids. The skewness and kurtosis of each contract were then determined. However, the sample kurtosis is not an unbiased estimator of the true kurtosis. If the tender bids are assumed to be normally distributed, this bias can be removed by using the adjusted kurtosis, that is, **Adjusted kurtosis = Kurtosis + [6/(n+1)]**. Thus, the skewness and adjusted kurtosis of the tender bids for different bidding sets (3,4,5...10 bidders) are computed as shown in table 9.36.

Table 9.36 : Skewness and adjusted kurtosis of tender bids

Number of bidders	Number of cases	Mean Skewness	Mean adjusted Kurtosis
3	277	0.02	*(0.00)
4	331	0.09	-0.04
5	317	0.12	0.08
6	288	0.07	0.02
7	76	0.07	0.00
8	43	0.05	0.06
9	12	0.14	-0.15
10	6	0.18	0.41
All bids	1350	0.076	0.016

(* when n=3, the adjusted kurtosis is always zero)

9.6.5.1.2 Testing for normality of tender bids

To test for normality of the tender bid distribution, let us consider the skewness and adjusted kurtosis of the tender bids for each category of bidding set separately. For the purpose of illustrating the test procedures, we conduct the normality test on one set of tender bids (number of bidders = 3) as described below.

As shown in table 9.36, there are 277 contracts (N) with three bidders. We compute the sample skewness of the *i* th case,

$$g_1^{(i)} \quad \text{for } i = 1 \text{ to } 277$$

If the bids are normal $N(\mu^{(i)}, \sigma^{(i)2})$, where $\mu^{(i)}$ and $\sigma^{(i)}$ may vary for each case, then each $g_1^{(i)}$ has a mean of zero and variance 6(n-2)/{(n+1)(n+3)} (denoted by V) as proved by Cramer (6) in section 29.37. Although the distribution of each $g_1^{(i)}$ is not normal, it is the same for each case (that is, for i=1,2,3 .....N). Thus, according to the Central Limit theorem, the mean of the skewness of the bids for the set of contracts , that is,

$$\bar{g} = \frac{g_1^{(1)} + g_1^{(2)} + \ldots + g_1^{(277)}}{277} \approx N(0, \frac{V}{N})$$

is approximately N(0,V/N), where N=277 in this instance.

Once the sample skewness and kurtosis of tender bids for different bidding sets (number of bidders = 3,4,5...10) are determined, we can then proceed to perform tests of normality on the skewness and kurtosis using the following methods:-

Method 1 :- z-test on skewness and kurtosis.

Method 2 :- Chi-square test on skewness and kurtosis.

In the z-test, we compute the $|\bar{g}|$ of each bidding set and then compare with $1.96\sqrt{\frac{V}{N}}$. If $|\bar{g}| > 1.96\sqrt{\frac{V}{N}}$, we reject the null hypothesis that the original tender bids are normally distributed, at the 5% significance level. This test can be conducted for each category of number of bidders (3,4,5,...10 bidders).

Alternatively, in method 2, we can combine the individual tests of each category of bidders into a single test. In this case, we compute $r_n = \left(\frac{\bar{g}}{\sqrt{\frac{V}{N}}}\right)$ and compare $\sum_{n=3}^{10} r_n^2$ with $\chi_m^2(P)$, where m = 10-2 = 8 and P is the significance level per cent. If $\sum_{n=3}^{10} r_n^2 >$ $\chi_m^2(P)$, we reject the null hypothesis that the original tender bids are normally distributed at the P per cent significance level. Similarly, the above procedures may be performed on the adjusted kurtosis to test normality of tender bids. The procedure is similar except that V is defined as follows:-

$$V = \frac{24n(n-2)(n-3)}{(n+1)^2(n+3)(n+5)}$$

and we ignore the cases when n=3 since the adjusted kurtosis is identically zero, so m = 10 - 3 = 7.

(i) z-test for skewness

The results of the z-tests for various categories of number of bidders are shown in table 9.37. From the table, it is observed that there are two groups of tender bids (contracts with 4 or 5 bidders) with $|\bar{g}| > 1.96\sqrt{\frac{V}{N}}$. We would expect rejection to occur in 5% of the tests on average, so this rather more than expected.

(ii) Chi-square test for skewness

Using the Chi-square test for normality, the value of $\sum_{n=3}^{10} r_n^2$ is 26.6813 as shown in table 9.38. We compare this value with the chi-square value in the chi-square distribution as shown in appendix F. The observed significance level is 0.001. Thus, we have strong statistical evidence to reject the null hypothesis of normality of the original tender bids. Therefore, based upon the test of skewness of the bids, the distribution of bids for refurbishment contracts is probably not normal.

Table 9.37 : Method 1 - Test of skewness of tender bids

Number of bidders	Number of cases	Mean skewness	$1.96\sqrt{\frac{V}{N}}$	Hypothesis
3	277	0.02	0.059	Accept
4	331	0.09	0.063	Reject
5	317	0.12	0.067	Reject
6	288	0.07	0.071	Accept
7	76	0.07	0.138	Accept
8	43	0.05	0.180	Accept
9	12	0.14	0.335	Accept
10	6	0.18	0.464	Accept

Table 9.38 : Method 2 - Test of skewness of tender bids

Number of bidders	Number of cases	Mean skewness	V	$r_n = \frac{\bar{x}}{\sqrt{\frac{V}{N}}}$	r_n^2
3	277	0.02	0.2500	0.666	0.4436
4	331	0.09	0.3429	2.796	7.8176
5	317	0.12	0.3750	3.489	12.1731
6	288	0.07	0.3810	1.925	3.7056
7	76	0.07	0.3750	0.997	0.9940
8	43	0.05	0.3636	0.544	0.2959
9	12	0.14	0.3500	0.820	0.6724
10	6	0.18	0.3357	0.761	0.5791
TOTAL					26.6813

(iii) z-test for adjusted kurtosis

As illustrated in table 9.39, there is only one category of bids (contracts with 5 bidders) where we reject the null hypothesis that the tender bids are normally distributed. We would expect rejection to occur in 1 test out of 20, so this is not conclusive either way.

(iv) Chi-square test of adjusted kurtosis

The chi-square test of adjusted kurtosis produced a computed value of $\sum_{n=4}^{10} r_n^2$ equal to 15.3664 as shown in table 9.40. We compare this value with the chi-square value in the chi-square distribution with 7 degrees of freedom, as shown in appendix F. The observed significance level is approximately 0.025. Therefore, we have moderate statistical evidence that the tender bids are not normally distributed.

Table 9.39 : Method 1 - Test of adjusted kurtosis of tender bids

Number of bidders	Number of cases	Mean adjusted Kurtosis	$1.96\sqrt{\frac{V}{N}}$	Hypothesis
4	331	-0.04	0.0376	Accept
5	317	0.08	0.0550	Reject
6	288	0.02	0.689	Accept
7	76	0.00	0.1487	Accept
8	43	0.06	0.2108	Accept
9	12	-0.15	0.4158	Accept
10	6	0.41	0.6039	Accept

Table 9.40 : Method 2 - Test of adjusted kurtosis of tender bids

Number of bidders	Number of cases	Mean adjusted kurtosis	V	$r_n = (\frac{\bar{x}}{\sqrt{\frac{V}{N}}})$	r_n^2
4	331	-0.04	0.1219	-2.084	4.3430
5	317	0.08	0.2020	2.849	8.1168
6	288	0.02	0.3562	0.569	0.3238
7	76	0.00	0.4375	0.000	0.0000
8	43	0.06	0.4973	0.558	0.3114
9	12	-0.15	0.5400	-0.707	0.4998
10	6	0.41	0.5696	1.331	1.7716
TOTAL					15.3664

From the above tests, it can be concluded that it is reasonable to fit the tender bids into either a Normal or Edgeworth distribution. The Edgeworth is theoretically more accurate but more complicated than the normal model. In our work the two models are quite similar, because the skewness and kurtosis coefficients are small.

9.6.5.1.3 Test of independence for distribution parameters

In order to adopt the Normal or Edgeworth distribution for prediction purposes, it is necessary to decide whether the parameters (skewness, adjusted kurtosis and coefficient of variation) of each respective distribution are affected by the number of bidders and job type. One-way analysis of variance tests were thus performed to test whether the population means of the above parameters are equal for different categories of number of bidders and job types. Theoretically, the following two conditions must be fulfilled before an one-way analysis of variance test could be properly carried out.

a) Each of the groups must be a random sample from a normal population.

b) The true variances in all groups must be equal.

Although these conditions are not satisfied, in practice, the one-way analysis of variance is still considered to be a robust procedure for the above data. The results of the analysis are shown in the SPSS-X output as displayed in tables 9.41 to 9.44.

(i) One-way analysis of variance of skewness by number of bidders

As indicated in table 9.41, the observed significance level is approximately 0.6836. Therefore, we accept the null hypothesis that the population means of skewness are the same for different numbers of bidders. This indicates that skewness of tender bids is not affected by the number of bidders.

Table 9.41 : One-way analysis of variance of skewness by number of bidders

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -

      Variable  SKEW
   By Variable  NOBID       number of bidders
                                   ANALYSIS OF VARIANCE

                                SUM OF           MEAN              F      F
      SOURCE           D.F.     SQUARES          SQUARES           RATIO  PROB.

BETWEEN GROUPS            7       1.7959           .2566           .6865  .6836
WITHIN GROUPS          1342     501.5162           .3737
TOTAL                  1349     503.3121
```

(ii) One-way analysis of variance of skewness by job type

Similarly, the test result for the one-way analysis of variance of skewness by job type has an observed significance level of 0.0321 as shown in table 9.42. Thus, we accept the null hypothesis that the population means of skewness are equal for different job types as 0.0321 is reasonably large.

Table 9.42 : One-way analysis of variance of skewness by job type

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - -

        Variable  SKEW
     By Variable  JOBTYPE     type of job
                                    ANALYSIS OF VARIANCE
```

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	7	5.7042	.8149	2.1977	.0321
WITHIN GROUPS	1342	497.6079	.3708		
TOTAL	1349	503.3121			

(iii) One-way analysis of variance of kurtosis by number of bidders

The one-way analysis of variance of kurtosis by number of bidders produced an observed significance level of approximately 0.0440 as shown in table 9.43. We accept the hypothesis that the population means of kurtosis are equal for different numbers of bidders as 0.0440 is reasonably large.

Table 9.43 : One-way analysis of variance of adjusted kurtosis by number of bidders

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - -

        Variable  ADJKURT
     By Variable  NOBID       number of bidders
                                    ANALYSIS OF VARIANCE
```

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	7	3.7155	.5308	2.0689	.0440
WITHIN GROUPS	1342	344.2896	.2565		
TOTAL	1349	348.0051			

(iv) One-way analysis of variance of kurtosis by job type

As for the testing of kurtosis for different job types, the observed significance level is approximately 0.7286 as shown in table 9.44. Since this probability is high, we accept the null hypothesis that the true mean kurtosis is independent of the type of job.

Table 9.44 : One-way analysis of variance of adjusted kurtosis by job type

```
- - - - - -  - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -

     Variable  ADJKURT
  By Variable  JOBTYPE     type of job
                                  ANALYSIS OF VARIANCE


                                 SUM OF          MEAN              F       F
        SOURCE           D.F.    SQUARES         SQUARES           RATIO   PROB.

BETWEEN GROUPS             7        1.1459          .1637          .6334   .7286
WITHIN GROUPS           1342      346.8592          .2585
TOTAL                   1349      348.0051
```

Thus, the results of one-way analysis of variance tests confirmed that both skewness and kurtosis of tender bids are independent of job type and number of bidders. The true skewness and kurtosis of tender bids for refurbishment contracts were thus estimated as shown in figures 9.21 and 9.22. The sample means of both the mean skewness and adjusted kurtosis of the each bidding set may be considered to be approximately equal to the true skewness and true kurtosis respectively, since the sample of tender bids is relatively large (1350 cases) and the estimates are unbiased. We conclude that, for our Edgeworth model, the values of true skewness and true kurtosis may be taken as 0.076 and 0.016 respectively. (These are the sample mean values from figures 9.21 and 9.22). For the normal model, we naturally have true skewness and true kurtosis equal to zero.

Figure 9.21 : Distribution of skewness of tender bids (1984 - 1987)

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY  4.00 OCCURRENCES

   1      -1.8
   4      -1.6  *
  13      -1.4  ***
  13      -1.2  ***
  40      -1.0  **********
  73       -.8  ******************
 117       -.6  *****************************
 129       -.4  ********************************
 117       -.2  *****************************
 179        .0  *********************************************
 154        .2  ***************************************
 162        .4  *****************************************
 154        .6  ***************************************
  80        .8  ********************
  49       1.0  ************
  44       1.2  ***********
  11       1.4  ***
   7       1.6  **
   2       1.8  *
   0       2.0
   1       2.2
                I....+....I....+....I....+....I....+....I....+....I
                0        40        80       120       160       200
                           HISTOGRAM FREQUENCY

MEAN          .076     STD ERR        .017     MEDIAN         .083
MODE         -.381     STD DEV        .611     VARIANCE       .373
KURTOSIS     -.286     S E KURT       .133     SKEWNESS      -.062
S E SKEW      .067     RANGE         3 965     MINIMUM      -1.762
MAXIMUM      2.203     SUM         102 014

VALID CASES    1360     MISSING CASES      0
```

Figure 9.22 : Distribution of adjusted kurtosis of tender bids (1984 - 1987)

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY  8.00 OCCURRENCES

   1     -1 25
  16     -1.00  **
 117      -.75  ***************
 170      -.50  *********************
 168      -.25  *********************
 148        00  ******************
 213       .25  ***************************
 117       .50  ***************
  46       .75  ******
  39      1.00  *****
  17      1.25  **
  10      1.50  *
   5      1.75  *
   1      2.00
   3      2.25
   2      2.50
   0      2.75
   0      3.00
   0      3.25
   0      3 50
   1      3.75
                I....+....I....+....I....+....I....+....I....+....I
                0        80       160       240       320       400
                           HISTOGRAM FREQUENCY

MEAN           .016     STD ERR        .017     MEDIAN        -.021
MODE          - 713     STD DEV        .570     VARIANCE       .325
KURTOSIS      2.327     S E KURT       .149     SKEWNESS       .965
S E SKEW       075      RANGE         4.783     MINIMUM      -1.132
MAXIMUM       3.651     SUM          17 609

CASES    1073      MISSING CASES     0


(NB· Only cases with 4 or more bids are computed as the adjusted kurtosis for
     3 bids is zero)
```

9.6.5.2 : Step 2 : Fitting of Edgeworth or Normal distribution

The fitting of the tender bid data into an Edgeworth distribution requires the determination of four main parameters namely: (i) true bid mean, (ii) true variance, (iii) true kurtosis, and (iv) true skewness. We have already discussed the determination of the true skewness and true kurtosis. We shall later discuss the determination of the true mean (μ). The true standard of deviation (σ) can be found if we know the true mean and the reciprocal of the true coefficient of variation ($\frac{\mu}{\sigma}$). The next section illustrates the estimation of the reciprocal of the true coefficient of variation.

9.6.5.2.1 Determination of an unbiased estimator for the reciprocal of true coefficient of variation of tender bids

Thus, it is desirable to determine an unbiased estimator for the reciprocal of the true coefficient of variation of the tender bids. The derivation of the unbiased estimator (R) was computed by Dr W.F. Scott (researcher's co-supervisor) as shown in appendix H. It is expressed as follows:-

R = Constant * (mean of bids / standard deviation of bids)

where standard deviation = $\sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n}}$

The following constants are appropriate in the calculations of R as shown Table 9.45.

Table 9.45 : Constants for R calculations

NUMBER OF BIDDERS	CONSTANTS
3	0.56419
4	0.72360
5	0.79788
6	0.84075
7	0.86863
8	0.88820
9	0.90270
10	0.91387

The mean values of R were determined for different bidding sets and different job types as shown in tables 9.46 and 9.47.

Table 9.46 : Mean values of R for different numbers of bidders

NO. OF BIDDERS	NO. OF CASES	MEAN VALUE OF R
3	277	14.476
4	231	15.953
5	317	18.542
6	288	17.850
7	76	18.639
8	43	17.089
9	12	20.349
10	6	24.965

Table 9.47 : Mean values of R for different job types

JOB TYPE	NO. OF CASES	MEAN VALUE OF R
1	63	17.181
2	30	20.564
3	468	19.760
4	96	16.013
5	55	18.313
6	17	19.167
7	130	19.561
8	491	13.228

9.6.5.2.2 Testing for independence of R against number of bidders, job type and bid mean

The unbiased estimator (R) was also tested for independence with respect to different numbers of bidders, job types and bid mean using the one-way analysis of variance test. In order to conduct the analysis of variance test of R for different bid mean, it is necessary to categorise the bid means into suitable groupings. The classification of the bid mean is shown in table 9.48 (in 1986 prices).

Table 9.48 : Classification of bid mean

CATEGORY	VALUE RANGE OF BID MEAN
1	Less than £100,000
2	£100,000 to £250,000
3	£250,000 to £500,000
4	£500,000 to £750,000
5	£750,000 to £1,000,000
6	£1,000,000 to £1,250,000
7	£1,250,000 to £1,500,000
8	£1,500,000 to £1,750,000
9	£1,750,000 to £2,000,000
10	£2,000,000 to £2,250,000
11	£2,250,000 to £2,500,000
12	£2,500,000 to £2,750,000
13	£2,750,000 to £3,000,000
14	More than £3,000,000

9.6.5.2.3 One-way analysis of variance of R by number of bidders, job type and bid mean

The results of the one-way analysis tests were shown in tables 9.49 to 9.51. As shown in table 9.49, the observed significance level is quite small (0.0079). Therefore, we reject the null hypothesis that the population means of R are the same for different numbers of bidders at the 1% significance level. This indicates that R is probably affected by the number of bidders, although we shall see (in tables 9.50 and 9.51) that the other two factors are more important.

Table 9.49 : One-way analysis of variance of R by number of bidders

```
- - - - - - -  - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -

      Variable  R
   By Variable  NOBID      number of bidders
                                  ANALYSIS OF VARIANCE
```

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	7	3803.9758	543.4251	2.7436	.0079
WITHIN GROUPS	1342	265810.8414	198.0707		
TOTAL	1349	269614.8172			

Similarly, the observed significance level is approximately 0 (as shown in table 9.50) for the one-way analysis of variance test of R for different job types. Thus, we also reject the null hypothesis that the population means of R are equal for different types of job. Therefore, we assume that R is also affected by job type.

Table 9.50 : One-way analysis of variance of R by job type

```
- - - - - -  - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -

      Variable  R
   By Variable  JOBTYPE    type of job
                                  ANALYSIS OF VARIANCE
```

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	7	12049.5195	1721.3599	8.9689	.0000
WITHIN GROUPS	1342	257565.2977	191.9265		
TOTAL	1349	269614.8172			

Table 9.51 : One-way analysis of variance of R by bid mean

```
- - - - - - -  - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -


        Variable  R
     By Variable  BMEAN
                                        ANALYSIS OF VARIANCE


                                      SUM OF         MEAN              F       F
        SOURCE              D.F.      SQUARES        SQUARES           RATIO   PROB.

BETWEEN GROUPS               13     24231.8745     1863.9903        10.1486   .0000
WITHIN GROUPS              1336    245382.9427      183.6699
TOTAL                      1349    269614.8172
```

As shown in table 9.51, the one-way analysis of variance of R against different categories of bid mean produced an observed significance level of 0. Hence, we reject the null hypothesis that the population means of R are the same for different categories of bid mean. We therefore assume that R is also affected by bid mean.

Thus, the above results show that the population mean of R varies according to the number of bidders, job type and bid mean. As a result, it is necessary to determine whether there is any interaction effect of the above factors (number of bidders, job type and bid mean) on R. The test of possible interaction effect of the factors on R was performed using the two-way analysis of variance test. The SPSS-X output of the tests were shown in tables 9.52 to 9.54.

9.6.5.2.4 Two-way analysis of variance of R by number of bidders, job type and bid mean

As shown in table 9.52, the F value associated with the bid mean (denoted by BMEAN) and job type interaction is 2.066. The observed significance level is approximately 0. Hence, we have strong statistical evidence that there is an interaction effect between the bid mean and job type.

The observed significance level for the testing of interaction effect between the number of bidders and bid mean on R is 0.433 as illustrated in table 9.53. Thus, we accept the null hypothesis that there is no interaction effect between the number of bidders and bid mean on R. Therefore, we have no statistical evidence that R is affected by the interaction of number of bidders and bid mean.

As illustrated in table 9.54, the observed significance level is approximately 0.112 for the interaction effect between number of bidders and job type. Similarly, we also accept the null hypothesis and statistically confirm that we have no evidence that R is affected by the interaction of number of bidders and job type.

Table 9.52 : Two-way analysis of variance of R by bid mean and job type

*** A N A L Y S I S   O F   V A R I A N C E ***

R
by BMEAN
JOBTYPE type of job

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	38453.446	20	1922.672	11.630	.000
BMEAN	26403.926	13	2031.071	12.286	.000
JOBTYPE	14221.571	7	2031.653	12.290	.000
2-Way Interactions	22204.911	65	341.614	2.066	.000
BMEAN JOBTYPE	22204.911	65	341.614	2.066	.000
Explained	60658.357	85	713.628	4.317	.000
Residual	208956.460	1264	165.314		
Total	269614.817	1349	199.863		

1350 cases were processed.
0 cases (.0 pct) were missing.

Table 9.53 : Two-way analysis of variance of R by number of bidders and bid mean

* * * A N A L Y S I S   O F   V A R I A N C E * * *

R
by NOBID number of bidders
BMEAN

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	25480.765	20	1274.038	6.942	.000
NOBID	1248.890	7	178.413	.972	.450
BMEAN	21676.789	13	1667.445	9.086	.000
2-Way Interactions	11801.977	63	187.333	1.021	.433
NOBID BMEAN	11801.977	63	187.333	1.021	.433
Explained	37282.741	83	449.190	2.448	.000
Residual	232332.076	1266	183.517		
Total	269614.817	1349	199.863		

1350 cases were processed.
0 cases (.0 pct) were missing.

Table 9.54 : Two-way analysis of variance of R number of bidders and job type

* * * A N A L Y S I S   O F   V A R I A N C E * * *

R
by NOBID number of bidders
JOBTYPE type of job

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	15759.074	14	1125.648	5.968	.000
NOBID	3709.555	7	529.936	2.810	.007
JOBTYPE	11955.099	7	1707.871	9.055	.000
2-Way Interactions	9041.669	37	244.369	1.296	.112
NOBID JOBTYPE	9041.669	37	244.369	1.296	.112
Explained	24800.744	51	486.289	2.578	.000
Residual	244814.073	1298	188.609		
Total	269614.817	1349	199.863		

1350 cases were processed.
0 cases (.0 pct) were missing.

9.6.5.2.5 Correlation and regression analysis of R

From the results of the two-way analysis of variance tests, it seems necessary to segregate the job type factor when determining the R value. Hence, the determination of any possible relationship between R and the number of bidders and bid mean (the actual bid mean value is adopted) is considered separately for different job types. Scatterplot and correlation analysis were performed to determine the nature and strength of linear relationship between R, number of bidders and bid mean. The SPSS-X output for the scatterplot of the above variables is displayed in appendix I. As observed in appendix I , the L-shaped plots of the data are not suitable for correlation analysis. Thus, as explained in chapter 9 section 9.3.4, the logarithm (base 10) transformation (transformation of all variables, that is, logarithm R, logarithm number of bidders and logarithm bid mean) is also adopted for the correlation analysis of the variables, as shown in appendix I. The correlation coefficients of both the untransformed and transformed variables are tabulated in tables 9.55 and 9.56.

Table 9.55 : Pearson Correlation Coefficient of R and number of bidders for different job types

Job Type	No. of cases	r	r (* logarithm)	Percentage points of r (1% Sig. level)
1	63	0.047	0.120	0.3223
2	30	-0.383	-0.351	0.4629
3	468	0.058	0.177	0.1192
4	96	0.227	0.291	0.2617
5	55	0.177	0.318	0.3446
6	17	0.219	0.392	0.6055
7	130	0.178	0.349	0.2252
8	491	0.165	0.248	0.1164

(Note : * indicates that both R and number of bidders are transformed using logarithm)

Table 9.56 : Pearson Correlation Coefficient of R and bid mean for different job types

Job Type	No. of cases	r	r (* logarithm)	Percentage points of r (1% Sig. level)
1	63	0.341	0.383	0.3223
2	30	0.068	-0.003	0.4629
3	468	0.161	0.332	0.1192
4	96	0.702	0.634	0.2617
5	55	0.243	0.492	0.3446
6	17	-0.001	-0.006	0.6055
7	130	0.469	0.578	0.2252
8	491	0.267	0.354	0.1164

(Note : * indicates that both R and bid mean are transformed using logarithm)

In order to determine whether there is significant association between the variables, we conduct the test at 1% significance level of the hypothesis that the true correlation coefficient is zero. We compare the modulus of r with r(0.5) from the correlation coefficient table as shown in appendix F. If the modulus of r is less than r(0.5), we accept the hypothesis at the 1% significance level. This suggests that there is no linear correlation between the variables. Conversely, if the modulus of r is greater than r(0.5), it indicates that there is significant linear correlation between the variables.

As shown in table 9.55, the moduli of r for all job types except job type 8 of the untransformed variables (R and number of bidders) are less than their corresponding table values [r(0.5)] for two-sided tests at the 1% significance level. This suggests there is no significant linear correlation between R and number of bidders for job types 1 to 7. However, there are some job types (job types 3, 4, 7, and 8) with significant correlation and some (job types 1,2, 5, and 6) without significant correlation after the logarithm transformation as illustrated in table 9.55. Table 9.56 shows that all except job types 2 and 6 have significant linear correlation between R and bid mean at the 1% significance level. The above results suggest that bid mean is a more important explanatory variable for R than number of bidders. Hence, regression analysis was performed using logarithm R as the dependent variable and logarithm bid mean and number of bidders as independent variables. A step-wise regression analysis was conducted so as to select the important variable(s) for the regression equations of logarithm R for different job types. The SPSS-X output of the regression analysis is displayed in appendix J. A summary of the respective regression equations for various job types is shown in table 9.57.

As illustrated in appendix J, the step-wise regression analysis shows that number of bidders is a less important variable for predicting the value of logarithm R (the probability associated with the F statistics exceeds 0.05). Hence, regression equations for logarithm R and logarithm bid mean were determined for various job types as shown in table 9.57, the variable n (number of bidders) being omitted. As expected, no regression equation is formed for job types 2 and 6 as the correlation coefficients of both job types are relatively small (see tables 9.55 and 9.56). Therefore, the value of R for these two job types may be considered to be equal to the mean value of R for the respective job types (Industrial=20.564 and Religious=19.167) as shown in table 9.46).

Table 9.57 : Regression equations for Log R for different job types

CODE	JOB TYPE	REGRESSION EQUATIONS
1	Transport and Utility	$Log R = -0.288 + 0.259 Log Bidmean$
3	Administration and Office	$Log R = -0.158 + 0.238 Log Bidmean$
4	Health and Welfare	$Log R = -1.201 + 0.421 Log Bidmean$
5	Refreshment, Entertainment and Recreation	$Log R = -0.917 + 0.372 Log Bidmean$
7	Education, Scientific and information	$Log R = -1.092 + 0.412 Log Bidmean$
8	Residential	$Log R = -0.346 + 0.243 Log Bidmean$

Note:
a) For job type 2 (Industrial buildings): R=20.564 and job type 6 (Religious buildings): R=19.167.
b) Bid mean is expressed at 1986 prices)
c) The above equations are only suitable for contracts up to £4m (bidmean).

9.6.5.3 Step 3 : Testing of bidding models

9.6.5.3.1 Testing of models on contractors A to E

The bidding models were tested on five contractors who have provided detailed tender bid information to the researcher. Three contractors provided only 14 contracts which they had tendered in 1986 while the remaining two contractors supplied 29 contracts which they have tendered recently (1987 to 1989). In order to test the model, it is necessary to divide the number of jobs supplied equally so that half the number of cases could be used to estimate the true bid mean of each new job while the remaining jobs may be utilised for testing the prediction accuracy of the model. For instance, if contractor A provides a total of 14 bids, 7 of the 14 will be used to determine the cost estimate and bid mean ratio while the remaining 7 will be used for testing the accuracy of the model. The test procedures for both the Normal and Edgeworth distribution models are as follows:-

a) Determine the cost estimate of new job.
b) Predict the true bid mean using past records (cost estimate / bid mean ratio).
c) Determine the value of R using the appropriate regression equation for the job type
d) Determine the number of bidders against whom the contractor is competing.
e) State the desired probability of success (P=0.20, 0.50 or 0.90).
f) Determine the k value from the Normal or Edgeworth distribution (appendix K).
g) Compute the theoretical new bid (Theoretical new bid = Predicted bid mean + k * true standard deviation of bids).
h) Compare the actual lowest bid with the theoretical new bid to determine the success rate achieved by both the prediction models.

The above test procedure is illustrated by testing on the tender bid records as provided by contractor A. Contractor A has supplied the researcher 29 contracts with each tender record containing the following information.

a) Date of tender.

b) Type of job.

c) Cost estimate of firm.

d) Tender bid of firm.

e) Tender bids of other competitors.

The data were keyed into a spreadsheet as illustrated in table 9.58. Let the first 14 jobs to be past tender records, while the next 15 jobs are future contracts used for testing the prediction model. Using the first 14 jobs, we compute the cost estimate/bid mean ratio for each contract and determine the average (denoted by Z) of these cost estimate/bid mean ratios. With the value of Z, we estimate the bid mean for the next 15 future contracts as shown in column 5 in table 9.58. Thereafter, using the respective regression equation for different job type, we compute Log R and subsequently the value of R for each of the 15 new contracts. Once R is determined, it is possible to compute the value of the true standard deviation of bids using the formula:- **true bid mean / R**. With the predicted bid mean and the true standard deviation of bids, the new theoretical bid for each contract can thus be computed using the appropriate k values as obtained from either the Normal or Edgeworth distribution (appendix K).

The test was conducted using three levels of probability (0.2, 0.5, 0.9) for both the Normal and Edgeworth distribution models. The results of the test for contractor A are shown in table 9.59. From the results, it would appear that both the Normal and Edgeworth bidding models provide very similar predictions. The above test procedures were also carried out on the other 4 contractors as shown in tables 9.60 to 9.63. Besides this, the margin by which a contractor has won or lost a contract was also computed as shown in tables 9.54 to 9.63. The margin analysis provides a measure to indicate the extent in which the predicted bids are close to the actual lowest bids. It is defined as follows:-

Margin = lowest bid - contractor's bid

Margin % = (lowest bid - contractor's bid) 100/contractor's bid

Weighted win margin = sum of win margins of successful bids / total value of successful contracts

Weighted lose margin = sum of lose margins of unsuccessful bids / total value of unsuccessful contracts

(Note: "Value" means contractor's bids)

If a contract is won (ie. the predicted bid of the contractor is lower than the lowest bid), the margin (win margin) is negative. Conversely, a positive margin (lose margin) indicates the reduction in the price which the contractor would have to make in order to win the contract.

9.6.5.3.2 Testing reliability and accuracy of bid predictions

In order to determine the reliability and accuracy of the bidding models, confidence interval tests and margin analysis were performed on the bid prediction results as shown in tables 9.64 and 9.65. As illustrated in tables 9.64 and 9.65, both Edgeworth and Normal models have 11 cases out of 15 (73.3%) where the theoretical success rate (P) falls within the 90% confidence interval. This shows that our bidding models are reasonably successful. That is, a contractor using our techniques with a given value of P (eg. 50%) will have approximately this success rate.

We now consider the win and lose margins (see tables 9.64b and 9.65b), and first consider the weighted win margins (%). These represent the relative proportionate loss of money by bidding too low when winning. They vary from about -4% to about -8% as P varies from 20% to 90%. (these margins are of course based on a fairly small sample). One would expect the win margin to behave like this as the probability of success increases, as with a high value of P one tends to win more contracts by bidding low. Let us now compare the actual experience of the 2261 refurbishment contracts described in section 9.3.1.3. The average win margin is -6.20% (which is measured as bid spread in figure 9.8). Since there were, on average, nearly 5 bidders (see figure 9.1) per job, this bid spread is to be compared with the -4% of our method when P=20%. This argument is, of course, only roughly applicable, but it shows that our win margins are probably smaller than the average for the industry.

The lose margins vary from about 5.6% to 3.5% as P varies from 20% to 90%. We would expect this trend, because in the case when P is 90% there will be comparatively few losing bids and they will tend to be only a little more than the winning bid.

The results of the Normal and Edgeworth models are quite similar as shown in tables 9.64 and 9.65. This suggests that both the Normal and Edgeworth models provide reasonably accurate tender bid predictions.

9.6.6 Conclusion

In conclusion, this module shows that tender bids of refurbishment contracts (lump sum contracts) may be fitted into either a Normal or Edgeworth distribution for the purpose of predicting the probability of success when submitting a tender bid. Both the Normal and Edgeworth distribution models were tested using tender bids provided by five refurbishment contractors. It was shown that both models predict quite similar and reasonably accurate results, as confirmed by the confidence interval test. The margin analysis showed that win margins were very probably better than the industry average. This implies that the models enable contractors to attain higher profitability in their contracts (as a result of reducing the amount of money lost by bidding too low when winning). However, it must be noted that the bidding models were tested on a relatively small sample of contracts (5 contractors, each with between 14 and 29 jobs) and thus should be applied in caution in practice.

Table 9.58 : Tender bid data of contractor A in spreadsheet format

CONTRACTOR A

JOBNO	NOBID	JOBTYPE	COST EST	BIDMEAN	COST EST/ BIDMEAN	PRED MEAN	LOG R	R	SIGMA
1	4	8	3523275	3904269	.90242				
2	4	2	1743348	1837959	.94852				
3	3	8	1354046	1379125	.98182				
4	6	8	1735962	1824534	.95146				
5	5	5	2614197	2888274	.90511				
6	3	3	1879234	2113266	.88926				
7	4	8	767062	827208	.92729				
8	4	8	2173209	2332746	.93161				
9	6	8	2032674	2080594	.97697				
10	6	7	3033774	3394883	.89363				
11	6	8	1542325	1537640	1.00305				
12	7	5	1009380	980062	1.02991				
13	6	8	5729941	5540836	1.03413				
14	5	3	822281	776295	1.05924				
15	5	8	2800911	2893439	.96802	2918832	1.2260	16.8285	173446
16	5	5	3460000	3838208	.90146	3605669	1.5222	33.2812	108340
17	7	8	1700105	1737873	.97827	1771681	1.1734	14.9059	118858
18	7	8	1093273	1096897	.99670	1139301	1.1268	13.3895	85089
19	4	5	458745	523565	.87619	478059	1.1958	15.6952	30459
20	5	3	1510769	1575693	.95880	1574374	1.3169	20.7449	75892
21	6	8	1846638	1871985	.98646	1924383	1.1821	15.2084	126534
22	6	3	495669	566030	.87569	516537	1.2017	15.9118	32463
23	6	8	3753637	4267829	.87952	3911668	1.2569	18.0694	216480
24	5	8	449296	522552	.85981	468212	1.0329	10.7874	43404
25	5	8	1701256	1664215	1.02226	1772880	1.1734	14.9083	118919
28	6	3	807674	973564	.82961	841678	1.2522	17.8725	47094
29	4	4	119391	139157	.85796	124417	.94	8.7891	14156
30	4	8	2726039	3269693	.83373	2840808	1.2232	16.7181	169924
31	3	3	1177035	1156019	1.01818	1226589	1.2911	19.5484	62746

AVERAGE COST ESTIMATE /BID MEAN RATIO FOR JOBS 1-14 : .95960

(Note : Sigma = true standard deviation of tender bids)

Table 9.59 : Testing of bidding model on Contractor A

(a) Edgeworth distribution model

TEST 1 . PROB : 0 2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
5	8	2918832	173446	- 44620	2841440	2707762	NO	-133678	-4.70
5	5	3605669	108340	-.44620	3557328	3336564	NO	-220764	-6.21
7	8	1771681	110858	-.72693	1685200	1610481	NO	-74719	-4.44
7	8	1139301	85089	-.72693	1077447	927639	NO	-149808	-13.90
4	5	478059	30459	- 22602	471175	467833	NO	-3342	-.71
5	3	1574374	75892	-.44620	1540511	1496051	NO	-44460	-2.89
6	8	1924383	126534	-.60461	1847879	1535765	NO	-312114	-16.89
6	3	516537	32463	-.60461	496910	505640	YES	8730	1.76
6	8	3911668	216480	-.60461	3780782	4052799	YES	272017	7.19
5	8	468212	43404	- 44620	448845	501084	YES	52239	11.64
5	8	1772880	118919	-.44620	1719818	1512261	NO	-207557	-12.07
6	3	841678	47094	-.60461	813204	851096	YES	37892	4 66
4	4	124417	14156	- 22602	121217	98091	NO	-23126	-19 08
4	8	2840808	169924	- 22602	2802402	2726039	NO	-76363	-2.72
3	3	1226589	62746	12011	1234125	1074943	NO	-159182	-12 90

ACTUAL SUCCESS RATE : 26 67%

TEST 2 PROB : 0 5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
5	8	2918832	173446	- 99737	2745842	2707762	NO	-38080	-1 39
5	5	3605669	108340	- 99737	3497614	3336564	NO	-161050	-4 60
7	8	1771681	110858	-1 22390	1626201	1610481	NO	-15720	- 97
7	8	1139301	85089	-1 22390	1035154	927639	NO	-107515	-10 39
4	5	478059	30459	- 82272	453000	467833	YES	14833	3 27
5	3	1574374	75892	- 99737	1498682	1496051	NO	-2631	- 18
6	8	1924383	126534	-1 12469	1782071	1535765	NO	-246306	-13 82
6	3	516537	32463	-1 12469	480026	505640	YES	25614	5 34
6	8	3911668	216480	-1 12469	3668195	4052799	YES	384604	10 48
5	8	468212	43404	- 99737	424922	501084	YES	76162	17 92
5	8	1772880	118919	- 99737	1654274	1512261	NO	-142013	-8 58
6	3	841678	47094	-1 12469	788712	851096	YES	62384	7 91
4	4	124417	14156	- 82272	112771	98091	NO	-14680	-13 02
4	8	2840808	169924	- 82272	2701008	2726039	YES	25031	93
3	3	1226589	62746	- 55326	1191874	1074943	NO	-116931	-9 81

ACTUAL SUCCESS RATE : 40 00%

TEST 3 PROB : 0 9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
5	8	2918832	173446	-1 90816	2587869	2707762	YES	119893	4 63
5	5	3605669	108340	-1 90816	3398939	3336564	NO	-62375	-1 84
7	8	1771681	110858	2 06735	1525960	1610481	YES	84521	5 54
7	8	1139301	85089	-2 06735	963392	927639	NO	-35753	-3 71
4	5	478059	30459	1 78892	423570	467833	YES	44263	10 45
5	3	1574374	75892	-1 90816	1429560	1496051	YES	66491	4 65
6	8	1924383	126534	1 99697	1671698	1535765	NO	-135933	-8 13
6	3	516537	32463	-1 99697	451709	505640	YES	53931	11 94
6	8	3911668	216480	-1 99697	3479364	4052799	YES	573435	16 48
5	8	468212	43404	-1 90816	385390	501084	YES	115694	30 02
5	8	1772880	118919	-1 90816	1545964	1512261	NO	-33703	-2 18
6	3	841678	47094	-1 99697	747633	851096	YES	103463	13 84
4	4	124417	14156	-1 78892	99093	98091	NO	-1002	-1 01
4	8	2840808	169924	-1 78892	2536828	2726039	YES	189211	7 46
3	3	1226589	62746	-1 61067	1125526	1074943	NO	-50583	-4 49

ACTUAL SUCCESS RATE : 60 00%

Table 9.59 : Testing of bidding model on Contractor A

(b) Normal distribution model

TEST 1 : PROB : 0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
5	8	2918832	173446	- 43644	2843133	2707762	NO	-135371	-4.76
5	5	3605669	108340	- 43644	3558385	3336564	NO	-221821	-6.23
7	8	1771681	118858	- 72158	1685915	1610481	NO	-75434	-4.47
7	8	1139301	85089	-.72158	1077902	927639	NO	-150263	-13.94
4	5	478059	30459	-.21420	471535	467833	NO	-3702	-.79
5	3	1574374	75892	- 43644	1541252	1496051	NO	-45201	-2.93
6	8	1924383	126534	- 59710	1848830	1535765	NO	-313065	-16.93
6	3	516537	32463	- 59710	497153	505640	YES	8487	1.71
6	8	3911668	216480	- 59710	3782408	4052799	YES	270391	7.15
5	8	468212	43404	- 43644	449269	501084	YES	51815	11.53
5	8	1772880	118919	- 43644	1720979	1512261	NO	-208718	-12.13
6	3	841678	47094	-.59710	813558	851096	YES	37538	4.61
4	4	124417	14156	- 21420	121385	98091	NO	-23294	-19.19
4	8	2840808	169924	- 21420	2804410	2726039	NO	-78371	-2.79
3	3	1226589	62746	13270	1234915	1074943	NO	-159972	-12.95

ACTUAL SUCCESS RATE : 26 67%

TEST 2 PROB : 0 5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
5	8	2918832	173446	- 99815	2745707	2707762	NO	-37945	-1 38
5	5	3605669	108340	- 99815	3497529	3336564	NO	-160965	-4.60
7	8	1771681	118858	-1 23132	1625329	1610481	NO	-14848	- 91
7	8	1139301	85089	-1 23132	1034529	927639	NO	-106890	-10 33
4	5	478059	30459	- 81933	453103	467833	YES	14730	3 25
5	3	1574374	75892	- 99815	1498622	1496051	NO	-2571	- 17
6	8	1924383	126534	-1 12900	1781526	1535765	NO	-245761	-13 79
6	3	516537	32463	-1 12900	479886	505640	YES	25754	5 37
6	8	3911668	216480	-1 12900	3667262	4052799	YES	385537	10 51
5	8	468212	43404	- 99815	424888	501084	YES	76196	17 93
5	8	1772880	118919	- 99815	1654181	1512261	NO	-141920	-8 58
6	3	841678	47094	-1 12900	788509	851096	YES	62587	7 94
4	4	124417	14156	- 81933	112819	98091	NO	-14728	-13 05
4	8	2840808	169924	- 81933	2701584	2726039	YES	24455	91
3	3	1226589	62746	- 54495	1192396	1074943	NO	-117453	-9 85

ACTUAL SUCCESS RATE : 40 00%

TEST 3 PROB : 0 9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
5	8	2918832	173446	-1 94320	2581792	2707762	YES	125970	4 88
5	5	3605669	108340	-1 94320	3395143	3336564	NO	-58579	-1 73
7	8	1771681	118858	-2 11052	1520829	1610481	YES	89652	5 89
7	8	1139301	85089	-2 11052	959719	927639	NO	-32080	-3 34
4	5	478059	30459	-1 81820	422676	467833	YES	45157	10 68
5	3	1574374	75892	-1 94320	1426901	1496051	YES	69150	4 85
6	8	1924383	126534	-2 03647	1666700	1535765	NO	-130935	-7 86
6	3	516537	32463	-2 03647	450427	505640	YES	55213	12 26
6	8	3911668	216480	-2 03647	3470813	4052799	YES	581986	16 77
5	8	468212	43404	-1 94320	383869	501084	YES	117215	30 54
5	8	1772880	118919	-1 94320	1541797	1512261	NO	-29536	-1 92
6	3	841678	47094	-2 03647	745772	851096	YES	105324	14 12
4	4	124417	14156	-1 81820	98677	98091	NO	-586	- 59
4	8	2840808	169924	-1 81820	2531839	2726039	YES	194200	7 67
3	3	1226589	62746	-1 63222	1124174	1074943	NO	-49231	-4 38

ACTUAL SUCCESS RATE : 60 00%

Table 9.60 : Testing of bidding model on Contractor B

(a) Edgeworth distribution model

TEST 1 PROB:0 2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	2	1147179	55786	- 22602	1134570	1084421	NO	-50149	-4.42
5	2	319489	13613	- 44620	313415	287630	NO	-25785	-8.23
4	8	1015422	77989	-.22602	997795	876789	NO	-121006	-12.13
5	8	502887	45816	- 44620	482444	455007	NO	-27437	-5.69
4	5	825254	42916	-.22602	815554	743502	NO	-72052	-8 83
4	7	439207	25697	- 22602	433399	385207	NO	-48192	-11.12
6	8	1030892	78886	- 60461	983197	1044103	YES	60906	6.19
6	7	1246630	47456	- 60461	1217938	1113837	NO	-104101	-8.55
6	3	842640	47135	- 60461	814142	662733	NO	-151409	-18.60
6	3	913194	50113	- 60461	882895	735491	NO	-147404	-16.70
6	7	957016	40624	- 60461	932454	913277	NO	-19177	-2.06
5	8	574216	50655	- 44620	551614	498379	NO	-53235	-9.65
5	8	474606	43852	-.44620	455039	456594	YES	1555	.34
6	5	7154281	166597	-.60461	7053555	6680621	NO	-372934	-5.29
5	7	467182	26648	- 44620	455292	445189	NO	-10103	-2.22

ACTUAL SUCCESS RATE : 13 33%

TEST 2 PROB:0 50

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	2	1147179	55786	- 82272	1101283	1084421	NO	-16862	-1.53
5	2	319489	13613	- 99737	305912	287630	NO	-18282	-5.98
4	8	1015422	77989	- 82272	951259	876789	NO	-74470	-7.83
5	8	502887	45816	- 99737	457191	455007	NO	-2184	-.48
4	5	825254	42916	- 82272	789946	743502	NO	-46444	-5 88
4	7	439207	25697	- 82272	418066	385207	NO	-32859	-7.86
6	8	1030892	78886	-1 12469	942170	1044103	YES	101933	10 82
6	7	1246630	47456	-1 12469	1193257	1113837	NO	-79420	-6.66
6	3	842640	47135	-1 12469	789628	662733	NO	-126895	-16 07
6	3	913194	50113	-1 12469	856832	735491	NO	-121341	-14 16
6	7	957016	40624	-1 12469	911327	913277	YES	1950	21
5	8	574216	50655	- 99737	523694	498379	NO	-25315	-4 83
5	8	474606	43852	- 99737	430869	456594	YES	25725	5 97
6	5	7154281	166597	-1 12469	6966911	6680621	NO	-286290	-4 11
5	7	467182	26648	- 99737	440604	445189	YES	4585	1 04

ACTUAL SUCCESS RATE-26 6"%

TEST 3 PROB:0 90

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	2	1147179	55786	-1 78892	1047382	1084421	YES	37039	3 54
5	2	319489	13613	-1 90816	293513	287630	NO	5883	-2 00
4	8	1015422	77989	-1 78892	875906	876789	YES	883	10
5	8	502887	45816	-1 90816	415463	455007	YES	39544	9 52
4	5	825254	42916	-1 78892	748481	743502	NO	4979	- 67
4	7	439207	25697	-1 78892	393237	385207	NO	-8030	-2 04
6	8	1030892	78886	-1 99697	873359	1044103	YES	170744	19 55
6	7	1246630	47456	-1 99697	1151862	1113837	NO	-38025	-3 30
6	3	842640	47135	-1 99697	748513	662733	NO	-85780	-11 46
6	3	913194	50113	-1 99697	813120	735491	NO	77629	-9 55
6	7	957016	40624	-1 99697	875891	913277	YES	37386	4 27
5	8	574216	50655	-1 90816	477558	498379	YES	20821	4 36
5	8	474606	43852	-1 90816	390929	456594	YES	65665	16 80
6	5	7154281	166597	-1 99697	6821592	6680621	NO	-140971	-2 07
5	7	467182	26648	-1 90816	416333	445189	YES	28856	6 93

ACTUAL SUCCESS RATE:53 33%

Table 9.60 : Testing of bidding model on Contractor B

(b) Normal distribution model

TEST 1 : PROB=0.20

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	2	1147179	55786	-.21420	1135230	1084421	NO	-50809	-4.48
5	2	319489	13613	-.43644	313548	287630	NO	-25918	-8.27
4	8	1015422	77989	-.21420	998717	876789	NO	-121928	-12.21
5	8	502887	45816	-.43644	482891	455007	NO	-27884	-5.77
4	5	825254	42916	-.21420	816061	743502	NO	-72559	-8.89
4	7	439207	25697	-.21420	433703	385207	NO	-48496	-11.18
6	8	1030892	78886	-.59710	983789	1044103	YES	60314	6.13
6	7	1246630	47456	-.59710	1218294	1113837	NO	-104457	-8.57
6	3	842640	47135	-.59710	814496	662733	NO	-151763	-18.63
6	3	913194	50113	-.59710	883272	735491	NO	-147781	-16.73
6	7	957016	40624	-.59710	932759	913277	NO	-19482	-2.09
5	8	574216	50655	-.43644	552108	498379	NO	-53729	-9.73
5	8	474606	43852	-.43644	455467	456594	YES	1127	.25
6	5	7154281	166597	-.59710	7054806	6680621	NO	-374185	-5.30
5	7	467182	26648	-.43644	455552	445189	NO	-10363	-2.27

ACTUAL SUCCESS RATE =13.33%

TEST 2 PROB:0.50

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	2	1147179	55786	-.81933	1101472	1084421	NO	-17051	-1.55
5	2	319489	13613	-.99815	305901	287630	NO	-18271	-5.97
4	8	1015422	77989	-.81933	951523	876789	NO	-74734	-7.85
5	8	502887	45816	-.99815	457156	455007	NO	-2149	-.47
4	5	825254	42916	-.81933	790092	743502	NO	-46590	-5.90
4	7	439207	25697	-.81933	418153	385207	NO	-32946	-7.88
6	8	1030892	78886	-1.12900	941830	1044103	YES	102273	10.86
6	7	1246630	47456	-1.12900	1193052	1113837	NO	-79215	-6.64
6	3	842640	47135	-1.12900	789425	662733	NO	-126692	-16.05
6	3	913194	50113	-1.12900	856616	735491	NO	-121125	-14.14
6	7	957016	40624	-1.12900	911152	913277	YES	2125	.23
5	8	574216	50655	-.99815	523655	498379	NO	-25276	-4.83
5	8	474606	43852	-.99815	430835	456594	YES	25759	5.98
6	5	7154281	166597	-1.12900	6966193	6680621	NO	-285572	-4.10
5	7	467182	26648	-.99815	440583	445189	YES	4606	1.05

ACTUAL SUCCESS RATE :26.67%

TEST 3 PROB:0.90

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	2	1147179	55786	-1.81828	1045744	1084421	YES	38677	3.70
5	2	319489	13613	-1.94320	293036	287630	NO	-5406	-1.84
4	8	1015422	77989	-1.81828	873616	876789	YES	3173	.36
5	8	502887	45816	-1.94320	413857	455007	YES	41150	9.94
4	5	825254	42916	-1.81828	747221	743502	NO	-3719	-.50
4	7	439207	25697	-1.81828	392483	385207	NO	-7276	-1.85
6	8	1030892	78886	-2.03647	870243	1044103	YES	173860	19.98
6	7	1246630	47456	-2.03647	1149987	1113837	NO	-36150	-3.14
6	3	842640	47135	-2.03647	746651	662733	NO	-83918	-11.24
6	3	913194	50113	-2.03647	811140	735491	NO	-75649	-9.33
6	7	957016	40624	-2.03647	874286	913277	YES	38991	4.46
5	8	574216	50655	-1.94320	475783	498379	YES	22596	4.75
5	8	474606	43852	-1.94320	389393	456594	YES	67201	17.26
6	5	7154281	166597	-2.03647	6815011	6680621	NO	-134390	-1.97
5	7	467182	26648	-1.94320	415400	445189	YES	29789	7.17

ACTUAL SUCCESS RATE :53.33%

Table 9.61 : Testing of bidding model on Contractor C

(a) Edgeworth distribution model

TEST 1 : PROB=0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	1035774	55182	-.2260	1023302	971999	NO	-51303	-5.01
6	3	798159	45222	-.6046	770817	756691	NO	-14126	-1.83
5	3	885795	48966	-.4462	863946	805614	NO	-58332	-6.75
4	3	2073301	93603	-.2260	2052147	2000549	NO	-51598	-2.51
5	3	1603575	76947	-.4462	1569241	1565481	NO	-3760	-.24
5	3	2178004	97189	-.4462	2134638	2042375	NO	-92263	-4.32
6	3	692060	40566	-.6046	667534	655417	NO	-12117	-1.82

ACTUAL SUCCESS RATE = 0%

TEST 2 : PROB=0.5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	1035774	55182	-.8227	990375	971999	NO	-18376	-1.86
6	3	798159	45222	-1.1247	747298	756691	YES	9393	1.26
5	3	885795	48966	-.9974	836958	805614	NO	-31344	-3.74
4	3	2073301	93603	-.8227	1996292	2000549	YES	4257	.21
5	3	1603575	76947	-.9974	1526830	1565481	YES	38651	2.53
5	3	2178004	97189	-.9974	2081071	2042375	NO	-38696	-1.86
6	3	692060	40566	-1.1247	646436	655417	YES	8981	1.39

ACTUAL SUCCESS RATE = 57.14%

TEST 3 : PROB=0.9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	1035774	55182	-1.7889	937058	971999	YES	34941	3.73
6	3	798159	45222	-1.9970	707852	756691	YES	48839	6.90
5	3	885795	48966	-1.9082	792360	805614	YES	13254	1.67
4	3	2073301	93603	-1.7889	1905853	2000549	YES	94696	4.97
5	3	1603575	76947	-1.9082	1456748	1565481	YES	108733	7.46
5	3	2178004	97189	-1.9082	1992552	2042375	YES	49823	2.50
6	3	692060	40566	-1.9970	611051	655417	YES	44366	7.26

ACTUAL SUCCESS RATE = 100%

Table 9.61 : Testing of bidding model on Contractor C

(b) Normal distribution model

TEST 1 : PROB=0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	1035774	55182	-.2142	1023954	971999	NO	-51955	-5.07
6	3	798159	45222	-.5971	771157	756691	NO	-14466	-1.88
5	3	885795	48966	-.4364	864424	805614	NO	-58810	-6.80
4	3	2073301	93603	-.2142	2053251	2000549	NO	-52702	-2.57
5	3	1603575	76947	-.4364	1569992	1565481	NO	-4511	-.29
5	3	2178004	97189	-.4364	2135587	2042375	NO	-93212	-4.36
6	3	692060	40566	-.5971	667838	655417	NO	-12421	-1.86

SUCCESS RATE = 0%

TEST 2 : PROB=0.5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	1035774	55182	-.8193	990562	971999	NO	-18563	-1.87
6	3	798159	45222	-1.1290	747103	756691	YES	9588	1.28
5	3	885795	48966	-.9982	836920	805614	NO	-31306	-3.74
4	3	2073301	93603	-.8193	1996609	2000549	YES	3940	.20
5	3	1603575	76947	-.9982	1526770	1565481	YES	38711	2.54
5	3	2178004	97189	-.9982	2080995	2042375	NO	-38620	-1.86
6	3	692060	40566	-1.1290	646261	655417	YES	9156	1.42

ACTUAL SUCCESS RATE = 57.14%

TEST 3 : PROB=0.9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	1035774	55182	-1.8183	935438	971999	YES	36561	3.91
6	3	798159	45222	-2.0365	706066	756691	YES	50625	7.17
5	3	885795	48966	-1.9432	790644	805614	YES	14970	1.89
4	3	2073301	93603	-1.8183	1903105	2000549	YES	97444	5.12
5	3	1603575	76947	-1.9432	1454052	1565481	YES	111429	7.66
5	3	2178004	97189	-1.9432	1989146	2042375	YES	53229	2.68
6	3	692060	40566	-2.0365	609449	655417	YES	45968	7.54

ACTUAL SUCCESS RATE = 100.00%

Table 9.62 : Testing of bidding model on Contractor D

(a) Edgeworth distribution model

TEST 1 : PROB = 0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	692820	40702	-.2260	683621	653374	NO	-30247	-4.42
4	3	995995	53537	-.2260	983895	971999	NO	-11896	-1.21
4	3	691393	40534	-.2260	682232	676789	NO	-5443	-.80
7	8	485971	44649	-.7269	453514	488967	YES	35453	7.82
5	3	115034	10335	-.4462	110423	107812	NO	-2611	-2.36
5	3	2203641	98049	-.4462	2159892	2042375	NO	-117517	-5.44
6	3	804661	45511	-.6046	777145	655417	NO	-121728	-15.66

ACTUAL SUCCESS RATE = 14.29%

TEST 2 : PROB = 0.5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	692820	40702	-.8227	659334	653374	NO	-5960	-.90
4	3	995995	53537	-.8227	951949	971999	YES	20050	2.11
4	3	691393	40534	-.8227	658045	676789	YES	18744	2.85
7	8	485971	44649	-1.2240	431322	488967	YES	57645	13.36
5	3	115034	10335	-.9974	104726	107812	YES	3086	2.95
5	3	2203641	98049	-.9974	2105850	2042375	NO	-63475	-3.01
6	3	804661	45511	-1.1247	753475	655417	NO	-98058	-13.01

ACTUAL SUCCESS RATE= 57.14%

TEST 3 : PROB = 0.9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	692820	40702	-1.7889	620007	653374	YES	33367	5.38
4	3	995995	53537	-1.7889	900222	971999	YES	71777	7.97
4	3	691393	40534	-1.7889	618881	676789	YES	57908	9.36
7	8	485971	44649	-2.0674	393666	488967	YES	95301	24.21
5	3	115034	10335	-1.9082	95313	107812	YES	12499	13.11
5	3	2203641	98049	-1.9082	2016548	2042375	YES	25827	1.28
6	3	804661	45511	-1.9970	713777	655417	NO	-58360	-8.18

ACTUAL SUCCESS RATE = 85.71%

Table 9.62 : Testing of bidding model on Contractor D

(b) Normal distribution model

TEST 1 : PROB = 0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	692820	40702	-.2142	684102	653374	NO	-30728	-4.49
4	3	995995	53537	-.2142	984527	971999	NO	-12528	-1.27
4	3	691393	40534	-.2142	682711	676789	NO	-5922	-.87
7	8	485971	44649	-.7216	453753	488967	YES	35214	7.76
5	3	115034	10335	-.4364	110523	107812	NO	-2711	-2.45
5	3	2203641	98049	-.4364	2160848	2042375	NO	-118473	-5.48
6	3	804661	45511	-.5971	777486	655417	NO	-122069	-15.70

ACTUAL SUCCESS RATE = 14.29%

TEST 2 : PROB = 0.5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	692820	40702	-.8193	659472	653374	NO	-6098	-.92
4	3	995995	53537	-.8193	952131	971999	YES	19868	2.09
4	3	691393	40534	-.8193	658182	676789	YES	18607	2.83
7	8	485971	44649	-1.2313	430994	488967	YES	57973	13.45
5	3	115034	10335	-.9982	104718	107812	YES	3094	2.95
5	3	2203641	98049	-.9982	2105773	2042375	NO	-63398	-3.01
6	3	804661	45511	-1.1290	753279	655417	NO	-97862	-12.99

ACTUAL SUCCESS RATE = 57.14%

TEST 3 : PROB = 0.9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	692820	40702	-1.8183	618812	653374	YES	34562	5.59
4	3	995995	53537	-1.8183	898650	971999	YES	73349	8.16
4	3	691393	40534	-1.8183	617691	676789	YES	59098	9.57
7	8	485971	44649	-2.1105	391738	488967	YES	97229	24.82
5	3	115034	10335	-1.9432	94951	107812	YES	12861	13.54
5	3	2203641	98049	-1.9432	2013112	2042375	YES	29263	1.45
6	3	804661	45511	-2.0365	711979	655417	NO	-56562	-7.94

ACTUAL SUCCESS RATE = 85.71%

Table 9.63 : Testing of bidding model on Contractor E

(a) Edgeworth distribution model

TEST 1 : PROB = 0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	676666	37879	-.22602	668105	653374	NO	-14731	-2.20
3	3	122849	10867	.12011	124154	120097	NO	-4057	-3.27
5	3	356609	24478	-.44620	345687	343852	NO	-1835	-.53
5	3	111507	10094	-.44620	107003	107812	YES	809	.76
4	3	1099989	9989	-.22602	1097731	1076150	NO	-21581	-1.97
5	3	259655	19221	-.44620	251079	256871	YES	5792	2.31
4	3	955013	51852	-.22602	943293	819596	NO	-123697	-13.11

ACTUAL SUCCESS RATE = 28.57%

TEST 2 : PROB = 0.5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	676666	37879	-.82272	645502	653374	YES	7872	1.22
3	3	122849	10867	-.55326	116837	120097	YES	3260	2.79
5	3	356609	24478	-.99737	332195	343852	YES	11657	3.51
5	3	111507	10094	-.99737	101440	107812	YES	6372	6.28
4	3	1099989	9989	-.82272	1091771	1076150	NO	-15621	-1.43
5	3	259655	19221	-.99737	240485	256871	YES	16386	6.81
4	3	955013	51852	-.82272	912353	819596	NO	-92757	-10.17

ACTUAL SUCCESS RATE= 71.43%

TEST 3 : PROB = 0.9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	676666	37879	-1.78892	608903	653374	YES	44471	7.30
3	3	122849	10867	-1.61067	105346	120097	YES	14751	14.00
5	3	356609	24478	-1.90816	309901	343852	YES	33951	10.96
5	3	111507	10094	-1.90816	92246	107812	YES	15566	16.87
4	3	1099989	9989	-1.78892	1082119	1076150	NO	-5969	-.55
5	3	259655	19221	-1.90816	222978	256871	YES	33893	15.20
4	3	955013	51852	-1.78892	862254	819596	NO	-42658	-4.95

ACTUAL SUCCESS RATE = 71.43%

Table 9.63 : Testing of bidding model on Contractor E

(b) Normal distribution model

TEST 1 : PROB = 0.2

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	676666	37879	-.21420	668552	653374	NO	-15178	-2.27
3	3	122849	10867	.13270	124291	120097	NO	-4194	-3.37
5	3	356609	24478	-.53644	343478	343852	YES	374	.11
5	3	111507	10094	-.53644	106092	107812	YES	1720	1.62
4	3	1099989	9989	-.21420	1097849	1076150	NO	-21699	-1.98
5	3	259655	19221	-.53644	249344	256871	YES	7527	3.02
4	3	955013	51852	-.21420	943906	819596	NO	-124310	-13.17

ACTUAL SUCCESS RATE = 42.86%

TEST 2 : PROB = 0.5

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	676666	37879	-.81933	645631	653374	YES	7743	1.20
3	3	122849	10867	-.54495	116927	120097	YES	3170	2.71
5	3	356609	24478	-.99815	332176	343852	YES	11676	3.51
5	3	111507	10094	-.99815	101432	107812	YES	6380	6.29
4	3	1099989	9989	-.81933	1091805	1076150	NO	-15655	-1.43
5	3	259655	19221	-.99815	240470	256871	YES	16401	6.82
4	3	955013	51852	-.81933	912529	819596	NO	-92933	-10.18

ACTUAL SUCCESS RATE = 71.43%

TEST 3 : PROB = 0.9

NOBID	JOBTYPE	PRED MEAN	SIGMA	K	NEW BID	LOW BID	SUCCESS	MARGIN	MARGIN(%)
4	3	676666	37879	-1.81828	607791	653374	YES	45583	7.50
3	3	122849	10867	-1.63222	105112	120097	YES	14985	14.26
5	3	356609	24478	-1.94320	309043	343852	YES	34809	11.26
5	3	111507	10094	-1.94320	91892	107812	YES	15920	17.32
4	3	1099989	9989	-1.81828	1081826	1076150	NO	-5676	-.52
5	3	259655	19221	-1.94320	222305	256871	YES	34566	15.55
4	3	955013	51852	-1.81828	860732	819596	NO	-41136	-4.78

ACTUAL SUCCESS RATE = 71.43%

Table 9.64 : Testing of bid predictions (Edgeworth distribution model)

(a) Confidence interval test

Theoretical success rate (P)= 20%

CONTRACTOR	NO OF JOBS	NO OF SUCCESSES	90% CONFIDENCE INTERVAL (CI)	DOES C.I. CONTAIN P?
A	15	4	0.1186 to 0.4759	Yes
B	15	2	0.0394 to 0.3226	Yes
C	7	0	0.0003 to 0.2325	Yes
D	7	1	0.0258 to 0.4404	No
E	7	2	0.1043 to 0.6592	Yes
TOTAL	51	9	0.0887 to 0.2643	Yes

Theoretical success rate (P) = 50%

CONTRACTOR	NO OF JOBS	NO OF SUCCESSES	90% CONFIDENCE INTERVAL (CI)	DOES C.I. CONTAIN P?
A	15	6	0.2169 to 0.6094	Yes
B	15	4	0.1186 to 0.4759	No
C	7	4	0.2808 to 0.8254	Yes
D	7	4	0.2808 to 0.8254	Yes
E	7	5	0.4071 to 0.9119	Yes
TOTAL	51	23	0.3813 to 0.5266	Yes

Theoretical success rate (P) = 90%

CONTRACTOR	NO OF JOBS	NO OF SUCCESSES	90% CONFIDENCE INTERVAL (CI)	DOES C.I. CONTAIN P?
A	15	9	0.3906 to 0.7831	No
B	15	8	0.3294 to 0.7286	No
C	7	7	0.7675 to 0.9997	Yes
D	7	6	0.5596 to 0.9742	Yes
E	7	5	0.4071 to 0.9119	Yes
TOTAL	51	35	0.6213 to 0.7512	No

(b) Margin analysis

CONTRACTOR	PROB. OF SUCCESS	NO. OF SUCCESSES	TOTAL WIN MARGIN (£)	TOTAL LOSE MARGIN (£)	WEIGHTED WIN MARGIN (%)	WEIGHTED LOSE MARGIN (%)
A	0.2	4	370878	-1405194	-6.69	7.44
B	0.2	2	62461	-1202983	-4.34	7.48
C	0.2	0	0	-283499	0	3.12
D	0.2	1	35453	-289439	-7.82	5.36
E	0.2	2	6601	-165901	-1.84	5.22
AVERAGE					-4.14	5.72
A	0.5	6	588628	-844926	-6.91	5.58
B	0.5	4	134193	-830362	-4.92	5.78
C	0.5	4	61282	-88415	-1.25	2.80
D	0.5	4	99525	-167493	-4.64	4.76
E	0.5	5	45548	-108378	-3.17	5.41
AVERAGE					-4.18	4.87
A	0.9	9	1350902	-319349	-9.96	3.63
B	0.9	8	400937	-361296	-7.46	3.29
C	0.9	7	394653	0	-4.70	0
D	0.9	6	296679	-58260	-6.39	8.89
E	0.9	5	142631	48627	-11.42	2.50
AVERAGE					-7.99	3.66

Table 9.65 : Testing of bid predictions (Normal distribution model)

(a) Confidence interval test

Theoretical success rate (P) = 20%

CONTRACTOR	NO OF JOBS	NO OF SUCCESSES	90% CONFIDENCE INTERVAL (CI)	DOES C.I. CONTAIN P?
A	15	4	0.1186 to 0.4759	Yes
B	15	2	0.0394 to 0.3226	Yes
C	7	0	0.0003 to 0.2325	Yes
D	7	1	0.0258 to 0.4404	No
E	7	3	0.1746 to 0.7192	Yes
TOTAL	51	10	0.1405 to 0.2517	Yes

Theoretical success rate (P) = 50%

CONTRACTOR	NO OF JOBS	NO OF SUCCESSES	90% CONFIDENCE INTERVAL (CI)	DOES C.I. CONTAIN P?
A	15	6	0.2169 to 0.6094	Yes
B	15	4	0.1186 to 0.4759	No
C	7	4	0.2808 to 0.8254	Yes
D	7	4	0.2808 to 0.8254	Yes
E	7	5	0.4071 to 0.9119	Yes
TOTAL	51	23	0.3813 to 0.5266	Yes

Theoretical success rate (P) = 90%

CONTRACTOR	NO OF JOBS	NO OF SUCCESSES	90% CONFIDENCE INTERVAL (CI)	DOES C.I. CONTAIN P?
A	15	9	0.3906 to 0.7831	No
B	15	8	0 3294 to 0.7286	No
C	7	7	0.7675 to 0.9997	Yes
D	7	6	0.5596 to 0.9742	Yes
E	7	5	0.4071 to 0.9119	Yes
TOTAL	51	35	0.6213 to 0.7512	No

(b) Margin analysis

CONTRACTOR	PROB. OF SUCCESS	NO. OF SUCCESSES	TOTAL WIN MARGIN (£)	TOTAL LOSE MARGIN (£)	WEIGHTED WIN MARGIN (%)	WEIGHTED LOSE MARGIN (%)
A	0.2	4	368231	-1415213	-6.64	7.48
B	0.2	2	61441	-1209353	-4.27	5 16
C	0.2	0	0	-288078	0	3.17
D	0.2	1	35214	-292432	-7.76	5.42
E	0.2	3	9621	-165382	-1.40	5.83
AVERAGE					-4.01	5.41
A	0.5	6	589258	-843081	-6.92	5.57
B	0.5	4	134763	-829620	-4.95	5.78
C	0.5	4	61394	-88488	-1.25	2.26
D	0.5	4	99542	-167358	-4.64	4 76
E	0.5	5	45371	-108588	-3.16	5 42
AVERAGE					-4.18	4.76
A	0.9	9	1383867	-300947	-10.22	3.43
B	0.9	8	415436	-346508	-7.75	2.75
C	0.9	7	410227	0	-5.14	0
D	0.9	6	306361	-56562	-6.61	8.63
E	0.9	5	145863	46812	-10.92	2.41
AVERAGE					-8.13	3.44

9.7 Module 6 - Risk management system

9.7.1 Questionnaire survey of risk management of contractors

In this study, the main research technique employed to identify the risk management strategies of contractors when tendering for refurbishment contracts is by means of questionnaire survey. A total of one hundred refurbishment contractors were surveyed. Forty-seven contractors responded and returned the survey questionnaires. This consists of twenty-seven refurbishment specialists and twenty general contractors from thirteen small, fifteen medium and nineteen large sized firms. The size of firm is classified according to the annual turnover of construction activities of the company as shown in table 9.66 below:-

Table 9.66 : Classification of size of firm

Turnover of Firm	Size of firm
Less than £20m	Small
Between £20m to £70m	Medium
Over £70m	Large

The classification of the firms into refurbishment specialists and general contractors is based solely on the response of the question relating to firm specialism. As such, this classification is based on what the contractors consider themselves to be or how other firms view the company in the refurbishment industry.

Three main categories of information were obtained through the survey questionnaire as follows:-

a) Tender adjudication factors.

b) Risk management strategy of contractors.

c) General information of firm.

9.7.1.1 Tender adjudication factors

(a) Ranking of tender adjudication factors

Table 9.67 provides a list of factors commonly considered by contractors during tender adjudication. The factors are arranged in ascending order ranked according to their respective mean score of rating. The mean scores of these factors range from a minimum of 2.68 to a maximum score of 6.34. This clearly shows that some factors are more significant than others. The more important tender adjudication factors include accuracy of cost estimate, credit worthiness of client, contractual liabilities, job type, client and consultant relationship with contractor, work load of contractor, complexity of work, job size and amendments to standard contract form.

The accuracy of cost estimate is ranked as the most important factor by all the contractors. The standard error of the mean score is 0.12 ($0.82 / \sqrt{47}$) thus giving an approximate 95% confidence interval for the true mean score of 6.10 (6.34 - 0.24) to 6.58 (6.34 + 0.24). The importance of attaining high accuracy in the cost estimate is self explanatory as it has undue influence on the profitability of the project and the chance of tender success. This finding is supported by the results obtained by Quah (1) in her study on risk management of refurbishment work.

The standard deviation of the various scores of other tender adjudication factors varies between 0.82 to 2.00 as shown in table 9.67. This measure provides an indication of the general agreement in the rating of various tender adjudication factors among the contractors. As shown in table 9.67, there is a general consensus in the rating of factors among the forty-seven contractors as evidenced by the relatively low standard deviations.

Table 9.67 : Ranking of tender adjudication factors

S/NO	TENDER ADJUDICATION FACTORS	RANK	MEAN SCORE	STD DEV
1	Accuracy of cost estimate	1	6.34	0.82
2	Credit worthiness of client	2	5.89	1.42
3	Contractual liabilities	3	5.77	1.13
4	Type of job	4	5.55	1.06
5	Relationship with consultants	5	5.53	1.14
6	Relationship with client	6	5.47	1.25
7	Work load commitment of contractor	7	5.32	1.22
8	Complexity of work	8	5.30	1.40
9	Size of job	9	5.28	1.23
10	Amendments to standard form	10	5.22	1.47
11	Management and expertise availability	11	5.17	1.10
12	Contract period	12	5.09	1.38
13	Job location	13	4.98	1.15
14	Number of bidders	14	4.84	1.49
15	Type of contract	15	4.60	1.35
16	Material, plant and labour availability	16	4.47	1.46
17	Identity of bidders	17	4.13	1.87
18	Proportion of priceable builder's work	18	4.11	1.37
19	Proportion of preliminaries	19	4.02	1.45
20	Economic conditions (job availability)	20	3.98	1.20
21	Inflation	21	3.93	1.56
22	Proportion of domestic sub-contractor's work	22	3.72	1.21
23	Proportion of NSC 'suppliers' work	23	3.67	1.08
24	Financial availability of contractor	24	3.66	2.00
25	Technological conditions	25	3.59	1.50
26	Scope for claims	26	3.28	1.75
27	Political conditions	27	2.68	1.55

Except for credit worthiness of client, amendments to standard form and complexity of work, the first ten adjudication factors in table 9.67 indicate that the distributions of the ratings of various factors are relatively narrow.

The differences in ratings of the above three factors could be attributed to the size and speciality of firms. Large and medium sized contractors normally conduct independent checks on the financial viability of clients in the early stage of tendering and thus do not consider clients' credit worthiness during tender adjudication. Furthermore, larger firms have much higher financial resources and thus their financial stability is not threatened by the relatively small refurbishment contracts (usually less than £3m).

The same reasoning applies to larger firms which have more capability to cope with more contractual liabilities as compared to small sized firms. The varied judgements on the complexity of work is mainly attributable to the relative experience and specialism of firms. Most refurbishment specialists are capable of undertaking a wide range of complicated projects. With such experience, they may sometimes consider what seems to be a complex job to a general contractor as relatively simple. Thus, the assessment of the complexity of a project is dependent on the capability and capacity of a firm.

(b) Classification of tender adjudication factors

A simple classification as depicted in table 9.68 was adopted to categorise all the tender adjudication factors into six groupings namely: (i) job characteristics, (ii) personnel relationship, (iii) contractual liabilities, (iv) resource availability, (v) work content, and (iv) market conditions.

The main purpose of this classification is to determine whether there is any aggregation of tender adjudication factors in any of these groupings. A visual inspection of the ratings assigned to various factors shows that most contractors tend to place more emphasis on personnel relationships when adjudicating their tender. This is plausibly due to the policies of many firms, particularly large and medium sized companies who desire to maintain good working relationships with clients and consultants.

From experience, most contractors have realised the potential benefits which accrue from establishing co-operative working relationships especially with consultants. With the co-operation of consultants, projects will be completed on time without much hindrance in the flow of work. Clients will be pleased to make payment especially when they can receive early returns for their investment as a result of timely completion of the project. Besides this, contractors are also more likely to be invited to tender for future contracts. This is particularly important especially in times of intense competition and in depressed market conditions.

Table 9.68 : Classification of tender adjudication factors

S/NO	CLASSIFICATION	TENDER ADJUDICATION FACTORS
1	Job characteristics	a) Type of job b) Size of job c) Job location d) Contract period e) Complexity of work
2	Personnel relationships	a) Relationship with client b) Relationship with consultant c) Credit worthiness of client
3	Contractual liabilities	a) Type of contract b) Amendments to standard form c) Contractual liabilities
4	Resource availability	a) Workload commitment of contractor b) Material, plant and labour availability c) Management and expertise availability
5	Work content	a) Accuracy of cost estimate b) Proportion of priceable builders' work c) Proportion of domestic sub-contractors' work d) Proportion of nominated sub-contractors' work e) Proportion of preliminaries f) Scope for claims
6	Market conditions	a) Political conditions b) Economic conditions (job availability) c) Technological conditions d) Inflation e) Number of bidders f) Identity of bidders

It was observed that factors in the market conditions category were rated to be of low importance to the contractors during tender adjudication. This is probably due to the fact that most contractors are generally aware of their local market conditions and thus do not rank these factors as vital when adjusting their tender during tender adjudication.

(c) Distributional characteristics of rating of tender adjudication factors

A frequency count analysis was performed on the rating responses of the tender adjudication factors as shown in table 9.69. This analysis determines the distribution pattern of the rating scores of various factors. From the analysis of the distributional patterns of the frequency response on various tender adjudication factors, five distinct distributional characteristics may be observed as shown in table 9.70. They are listed as follows:-

i) Factors with significantly negatively skewed distribution.

ii) Factors with slightly negatively skewed distribution.

iii) Factors with normal distribution.

iv) Factors with significantly positively skewed distribution.

v) Factors with uniform / bi-modal distribution.

Examples of each distributional characteristic are displayed in figures 9.23 to 9.28.

Table 9.69 : Frequency analysis of rating scores of tender adjudication factors

S/NO	TENDER ADJUDICATION FACTORS	FREQUENCY COUNT FOR DIFFERENT RATINGS						
		1	2	3	4	5	6	7
1	Accuracy of cost estimate	0	0	0	2	4	17	24
2	Credit worthiness of client	1	2	0	3	5	17	19
3	Contractual liabilities	0	1	1	3	11	18	13
4	Type of job	0	0	2	5	14	17	9
5	Relationship with consultants	0	0	0	13	7	16	11
6	Relationship with client	0	0	1	14	7	12	13
7	Work load commitment of contractor	0	1	1	10	15	10	10
8	Complexity of work	0	1	5	6	13	9	12
9	Size of job	0	1	4	6	13	16	7
10	Amendments to standard form	1	1	3	9	11	10	11
11	Management and expertise availability	0	0	2	12	14	12	6
12	Contract period	0	3	1	12	13	9	9
13	Job location	0	0	4	14	13	11	5
14	Number of bidders	0	4	5	7	8	7	6
15	Type of contract	0	3	8	11	10	13	2
16	Material, plant and labour availability	3	2	2	17	12	8	3
17	Identity of bidders	4	7	8	7	8	7	6
18	Proportion of priceable builder's work	1	5	9	15	8	8	1
19	Proportion of preliminaries	3	4	6	18	8	5	2
20	Economic conditions (job availability)	2	3	7	21	8	5	0
21	Inflation	5	3	5	18	7	5	2
22	Proportion of domestic sub-contractor's work	2	5	11	17	8	3	0
23	Proportion of NSC/suppliers' work	1	7	9	18	11	0	0
24	Financial availability of contractor	10	6	2	9	9	4	4
25	Technological conditions	6	5	7	17	7	3	1
26	Scope for claims	8	11	8	8	7	2	3
27	Political conditions	11	16	6	10	1	1	2

Table 9.70 : Distributional characteristics of ratings of tender adjudication factors

TENDER ADJUDICATION FACTORS	SKEWNESS	KURTOSIS
A) SIGNIFICANTLY NEGATIVELY SKEWED FACTORS		
1) Accuracy of cost estimate	-1.22	1.16
2) Credit worthiness of client	-1.86	3.56
3) Contractual liabilities	-1.13	1.75
B) SLIGHTLY NEGATIVELY SKEWED FACTORS		
1) Type of job	-0.49	-0.15
2) Relationship with consultants	-0.17	-1.38
3) Relationship with client	-0.14	-1.42
4) Work load commitment of contractor	-0.28	-0.25
5) Complexity of work	-0.42	-0.68
6) Size of job	-0.63	-0.07
7) Amendments to standard form	-0.65	0.18
8) Management and expertise availability	0.05	-0.80
9) Contract period	-0.37	-0.24
10) Job location	0.13	-0.82
11) Type of contract	-0.21	-0.89
12) Material, plant and labour availability	-0.62	0.56
C) NORMALLY DISTRIBUTED FACTORS		
1) Proportion of priceable builder's work	-0.04	-0.52
2) Proportion of preliminaries	-0.18	0.01
3) Proportion of domestic sub-contractor's work	-0.22	-0.09
4) Proportion of NSC/suppliers' work	-0.53	-0.52
5) Economic conditions (job availability)	-0.44	0.47
6) Inflation	-0.26	-0.15
7) Technological conditions	-0.16	-0.36
D) SIGNIFICANTLY POSITIVELY SKEWED FACTORS		
1) Scope for claims	0.49	-0.60
2) Political conditions	1.08	0.97
E) UNIFORMLY / BI-MODALLY DISTRIBUTED FACTORS		
1) Number of bidders	-0.37	-0.69
2) Identity of bidders	-0.03	-1.11
3) Financial availability of contractor	0.02	-1.22

Figure 9.23 : Significantly negatively skewed factor

(accuracy of cost estimate)

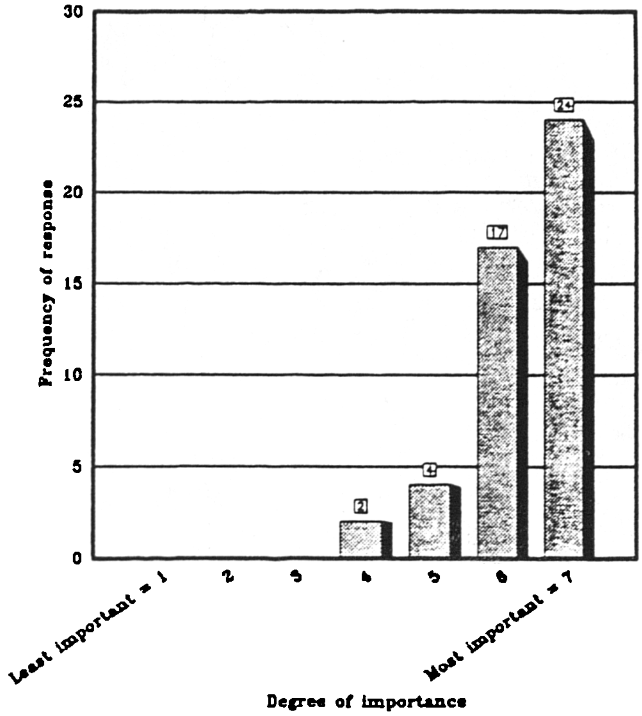


Figure 9.24 : Slightly negatively skewed factor

(size of job)

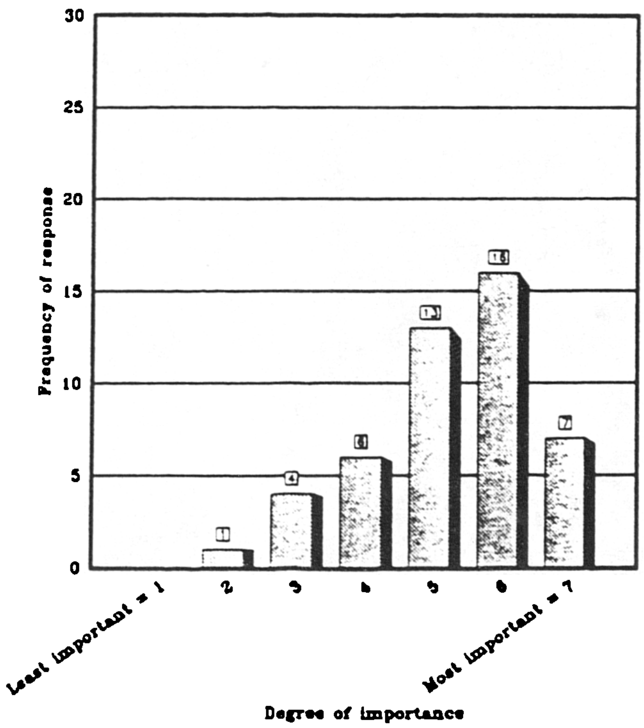


Figure 9.25 : Normally distributed factor (proportion of priceable builder's work)

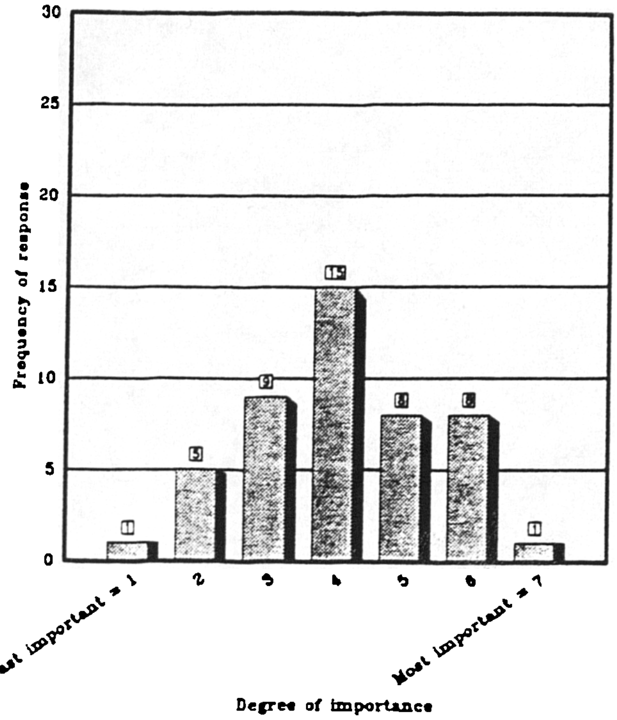


Figure 9.26 : Significantly positively skewed factor (political conditions)

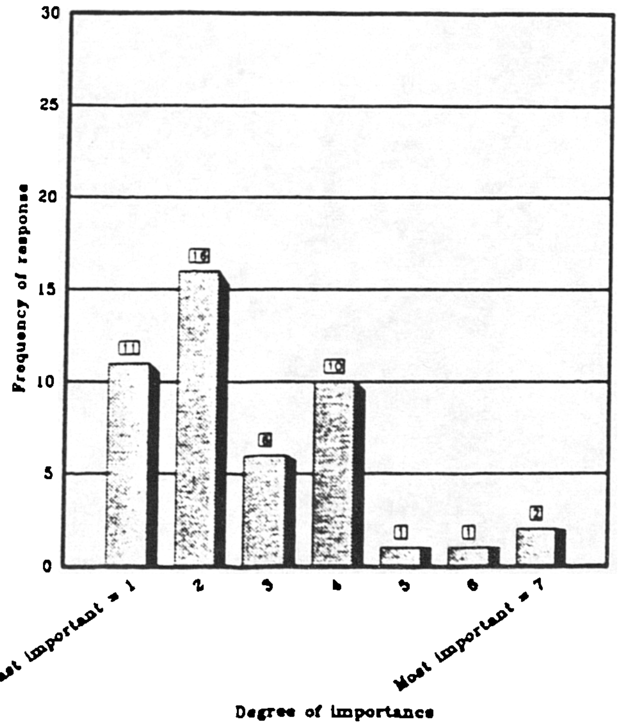


Figure 9.27 : Uniformly distributed factor

(identity of bidders)

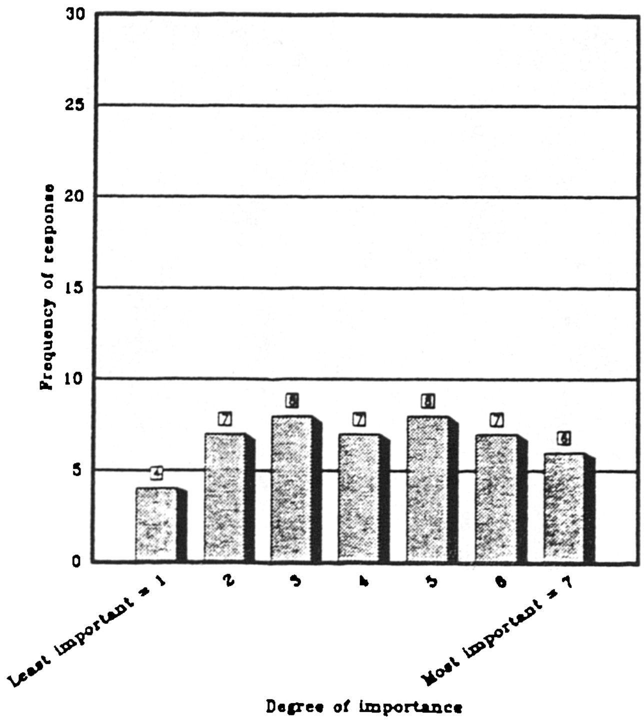
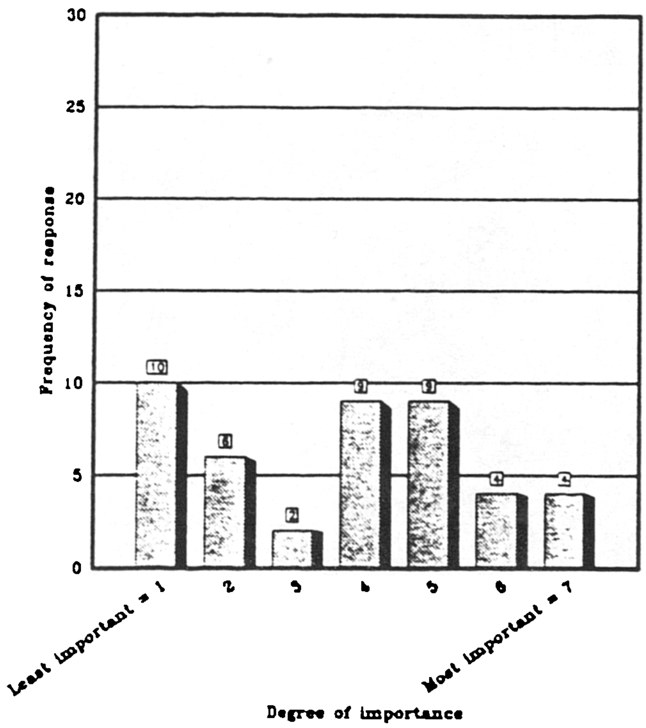


Figure 9.28 : Bi-modally distributed factor

(financial availability of contractor)



Factors with significantly negatively skewed distributions refer to those which the contractors consider as extremely important in affecting their decisions during tender adjudication. These include accuracy of cost estimate, credit worthiness of client and contractual liabilities.

The second category of factors as in table 9.70 have responses scattered mainly between ratings 4, 5 and 6. Most contractors share similar opinions that such factors are significant but not extremely important. However, there are some contractors who regard these factors to be of lesser importance. For instance, as indicated in table 9.69, some contractors have rated material, plant and labour availability as extremely important while some have rated it as the least important. The differences in such judgements may be attributed to the difference in size of firms. As explained before, larger firms have more resource capacity and thus do not encounter many difficulties in undertaking most refurbishment work.

The third group of factors have ratings which are normally distributed. In this category, judgements among contractors vary considerably and a large proportion of contractors have rated the factors to be of average importance. These factors refer mainly to the constituents of work (distribution of work between main and sub-contractors) and the general economic conditions. As observed from the mean scores of these factors in table 9.71, small sized firms have relatively higher scores than medium and large sized contractors.

This implies that smaller firms are more concerned with the composition of work and fluctuations of economic conditions. One possible reason for this trend is that small sized firms have limited capacities and capabilities and are generally more vulnerable to economic fluctuations (bankruptcy).

Political conditions and scope for claims have been considered by most contractors to be of least importance when adjudicating a tender. This result shows that contractors are generally not too concerned about these factors when pricing their tenders. This finding is rather surprising and contradictory to the results obtained by Quah (1). In an investigation of forty-two refurbishment contractors, she found that tender documentation in refurbishment work contains more contentious items of work providing many opportunities for scope of claims by contractors. However, in this study a total of twenty-two refurbishment contractors were interviewed, and only one contractor mentioned that scope of claims has undue influence on his firm's tendering strategy. While most contractors prefer to tender for contracts where the scope of work is well defined in unambiguous tender documentation. Perhaps the present trend towards negotiated contracts especially for large and medium sized firms is accountable for this change of contractor's attitude in using scope for claims as a tendering strategy. This trend is also explicitly expressed by some contractors who remarked that they would prefer to know the actual commitment of resources for a proposed job instead of relying on contentious items in the tender documentation for making a profit.

(d) Analysis of variance of tender adjudication factors by firm size

A two-way analysis of variance test (using Minitab's LPLOT and TWOWAY ANOVA procedures) was conducted to determine whether the mean score of rating is affected by different tender adjudication factors and different size of firm. The mean scores of rating of the various sizes of firms for different tender adjudication factors are shown in table 9.71 while the Minitab' LPLOT and TWOWAY ANOVA are displayed in figure 9.29. There seem to be some systematic differences among small, medium and large sized firms for various tender adjudication factors. The mean scores of medium and large sized firms are also consistently lower than the small sized firms for most factors. Large sized contractors also have significantly lower mean scores for the following factors:-

a) Number of bidders.

b) Material, plant and labour availability.

c) Proportion of priceable builder's work.

d) Proportion of preliminaries.

e) Economic conditions.

f) Proportion of domestic sub-contractors' work.

g) Proportion of nominated sub-contractors' work.

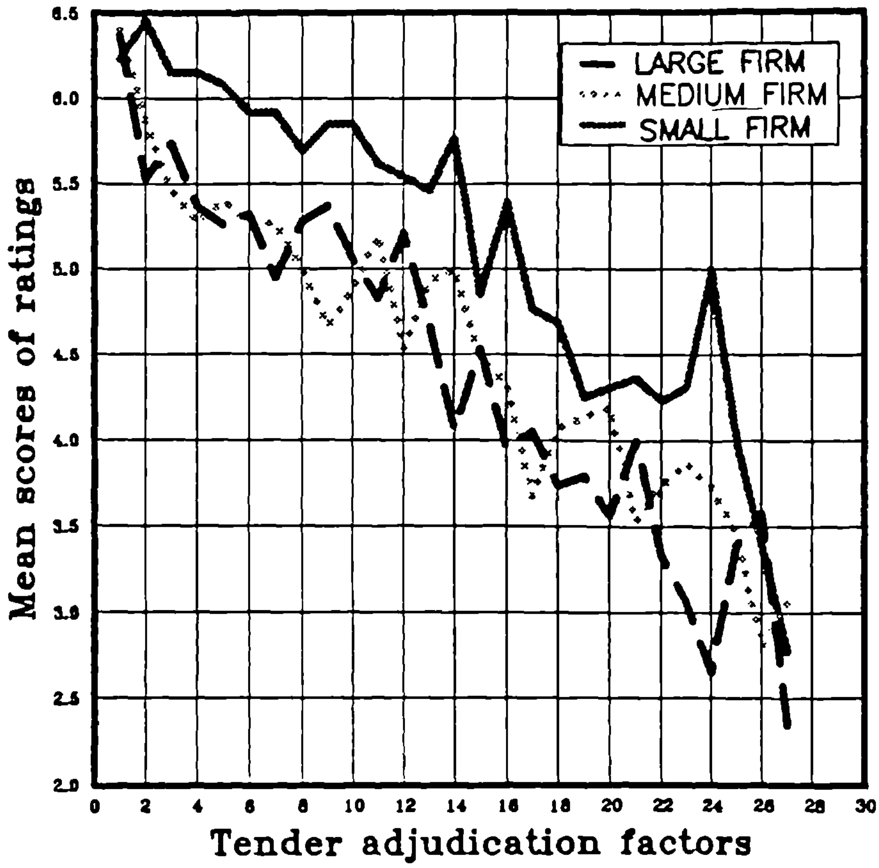
h) Finance availability of contractor.

i) Management and expertise availability.

Table 9.71 : Comparison of mean scores of tender adjudication factors by size of firm

S/NO	TENDER ADJUDICATION FACTORS	MEAN SCORES OF RATINGS		
		SMALL FIRM	MEDIUM FIRM	LARGE FIRM
1	Accuracy of cost estimate	6.23	6.40	6.37
2	Credit worthiness of client	6.46	5.87	5.53
3	Contractual liabilities	6.15	5.47	5.74
4	Type of job	6.15	5.27	5.37
5	Relationship with consultants	6.08	5.40	5.26
6	Relationship with client	5.92	5.27	5.32
7	Work load commitment of contractor	5.92	5.27	4.95
8	Complexity of work	5.69	5.00	5.28
9	Size of job	5.85	4.67	5.37
10	Amendments to standard form	5.85	4.87	5.06
11	Management and expertise availability	5.62	5.20	4.83
12	Contract period	5.54	4.53	5.21
13	Job location	5.46	4.93	4.68
14	Number of bidders	5.77	5.00	4.06
15	Type of contract	4.85	4.47	4.53
16	Material, plant and labour availability	5.39	4.33	3.95
17	Identity of bidders	4.77	3.67	4.05
18	Proportion of priceable builder's work	4.69	4.07	3.74
19	Proportion of preliminaries	4.25	4.13	3.79
20	Economic conditions (job availability)	4.31	4.20	3.56
21	Inflation	4.36	3.53	4.00
22	Proportion of domestic sub-contractor's work	4.23	3.73	3.33
23	Proportion of NSC/suppliers' work	4.31	3.87	3.06
24	Financial availability of contractor	5.00	3.73	2.65
25	Technological conditions	4.00	3.47	3.39
26	Scope for claims	3.39	2.80	3.58
27	Political conditions	2.77	3.07	2.32

Figure 9.29 : Minitab LPLOT and TWO-WAY ANOVA of mean rating scores of tender adjudication factors by size of firm



TWO-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
FACTORS	26	64.635	2.486
SIZE	2	8.583	4.291
ERROR	52	5.741	0.110
TOTAL	80	78.958	

(Note: Tender adjudication factors are arranged according to table 9.67)

The above factors are mainly concerned with resource availability. Large firms do not have much difficulty in obtaining resources as most refurbishment contracts are of relatively small sizes as compared to new build work (in terms of contract value). Furthermore, with their resource capacity and capability, larger firms also have more flexibility in tendering for a wider range of refurbishment jobs. As such, they are less affected by the above factors during tender adjudication.

The two-way analysis of variance output is shown in figure 9.29 displaying the sum of squares (SS), degree of freedom (DF) and the mean square of both the tender adjudication factors and the size of firm. To determine whether there is statistically significant evidence of a difference in the mean score among different sizes of firm, we compute the F-ratio : (MS SIZE) / (MS ERROR) = 4.291 / 0.110 = 39.009. We compare this result with the value from the F-table (appendix F) corresponding to 2 degrees of freedom in the numerator and 52 degrees of freedom in the denominator. The F-value is 3.183 at the 5% significance level. Since 39.009 is much greater than 3.183, we have very strong statistical evidence that the mean score varies between small, medium and large sized firms. This confirms the finding based on examination of figure 9.29.

Similarly, the computed F-ratio for the tender adjudication factors is (MS FACTORS) / (MS ERROR) = 2.486 / 0.110 = 22.600. This value is also significantly greater than the corresponding F-table value of 1.737 with 26 degrees of freedom in the numerator and 52 degrees of freedom at the 5% significance level. Therefore, we also have strong statistical evidence that the mean score varies among different tender adjudication factors.

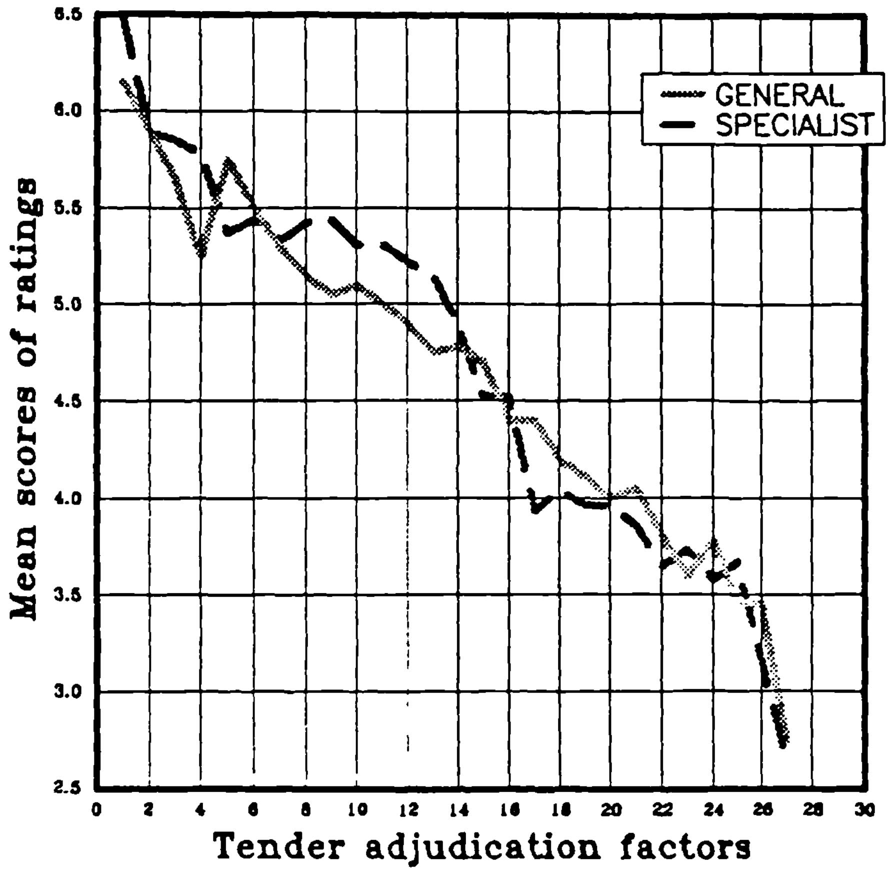
(e) Analysis of variance of tender adjudication factors and specialism of firm

A similar comparison of the mean rating scores was also made between refurbishment specialists and general contractors as shown in table 9.72. As displayed in figure 9.30, the LPLOT of both refurbishment specialists and general contractors displays very similar characteristics. Except for factors such as job type, complexity of work, job size, amendments to standard form, management and expertise availability, contract period, job location and identity of bidders, there is no significant difference in the mean scores of other tender adjudication factors. It was observed that those factors that are different (assigned different ratings by specialist and general contractors) are mainly related to job characteristics. This could be attributed to the nature and complexity of jobs undertaken by the contractors. Refurbishment specialists usually tender for relatively larger and more complex projects and thus would consider factors such as job type, complexity, job location and management expertise as important factors influencing their pricing decisions. Conversely, general contractors especially small refurbishment firms normally undertake a wider range of simpler refurbishment jobs. As such, the above factors are less frequently or not considered when they are adjudicating their tender.

Table 9.72 : Comparison of mean scores of tender adjudication factors by specialism of firm

S/NO	TENDER ADJUDICATION FACTORS	MEAN SCORES OF RATINGS	
		SPECIALIST CONTRACTORS	GENERAL CONTRACTORS
1	Accuracy of cost estimate	6.48	6.15
2	Credit worthiness of client	5.89	5.90
3	Contractual liabilities	5.85	5.65
4	Type of job	5.78	5.25
5	Relationship with consultants	5.37	5.75
6	Relationship with client	5.44	5.50
7	Work load commitment of contractor	5.33	5.30
8	Complexity of work	5.42	5.15
9	Size of job	5.44	5.05
10	Amendments to standard form	5.31	5.10
11	Management and expertise availability	5.31	5.00
12	Contract period	5.22	4.90
13	Job location	5.15	4.75
14	Number of bidders	4.89	4.78
15	Type of contract	4.52	4.70
16	Material, plant and labour availability	4.52	4.40
17	Identity of bidders	3.93	4.40
18	Proportion of priceable builder's work	4.04	4.20
19	Proportion of preliminaries	3.96	4.11
20	Economic conditions (job availability)	3.96	4.00
21	Inflation	3.85	4.05
22	Proportion of domestic sub-contractor's work	3.65	3.80
23	Proportion of NSC/suppliers' work	3.73	3.60
24	Financial availability of contractor	3.58	3.78
25	Technological conditions	3.67	3.47
26	Scope for claims	3.15	3.45
27	Political conditions	2.63	2.75

Figure 9.30 : Minitab LPLOT and TWO-WAY ANOVA of mean rating scores of tender adjudication factors by specialism of firm



TWO-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
FACTORS	26	42.6334	1.6397
SPECIAL	1	0.0235	0.0235
ERROR	26	0.8783	0.0338
TOTAL	53	43.5352	

(Note: Tender adjudication factors are arranged according to table 9.67)

As shown in figure 9.30, the F-ratio for the specialist contractors is (MS SPECIAL) / (MS ERROR) = 0.0235 / 0.0338 = 0.695. We compare this value with the F-table value with 1 degree of freedom in the numerator and 26 in the denominator. The F-table value is 4.225 at the 5% significance level. Since 0.695 is much lesser than 4.225, we have no statistical evidence that mean score differs between refurbishment specialists and general contractors.

(f) Analysis of variance of tender adjudication factors and position of respondent

The comparison of mean scores of rating between directors and estimators is shown in table 9.73. As illustrated in figure 9.31, the LPLOT shows that there is no discernible difference in the ratings of various tender adjudication factors between directors and estimators. The close plots as shown in figure 9.31 indicate that directors and estimators share similar opinion in assessing the importance of various factors when adjudicating a tender. The F-ratio obtained is (MS DIRECTOR) / (MS ERROR) = 0.2364 / 0.0847 = 2.791. Comparing with the F-table value in appendix F with 1 degree of freedom in the numerator and 26 in the denominator. The F-table value is 4.225 at the 5% significance level. Since 2.791 is less than 4.225, we have no statistical evidence that mean score varies between directors and estimators.

(g) Decision making strategy of contractors

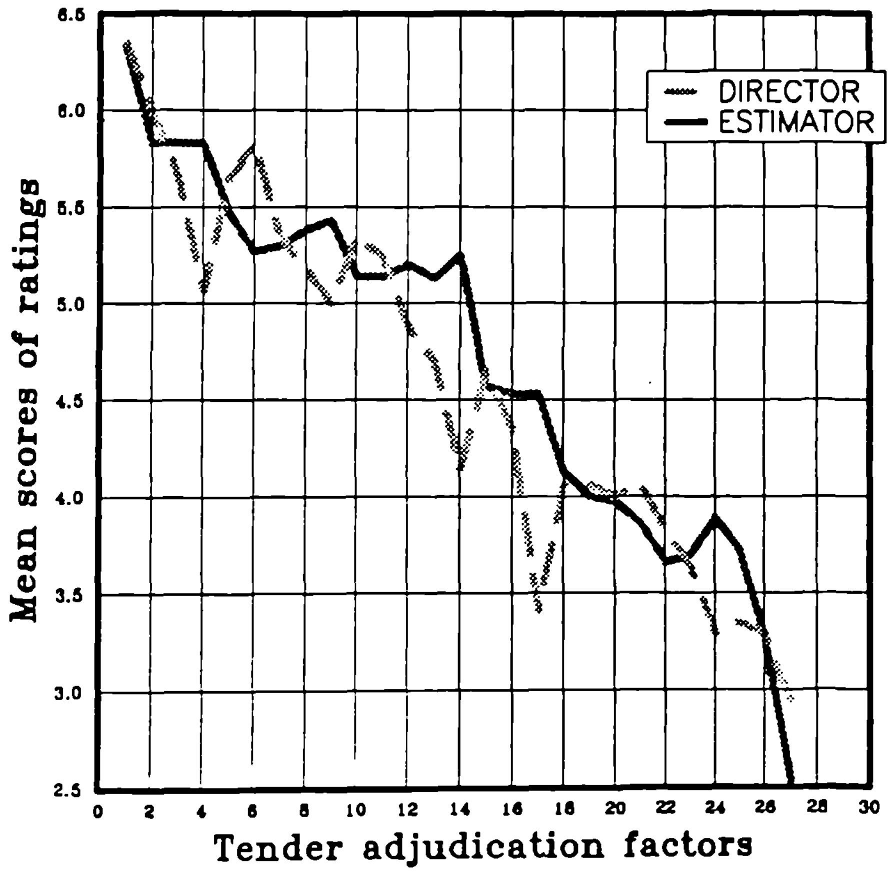
Figure 9.32 shows that 37 contractors (78.72%) adopt group decision making while adjudicating a tender as compared to 10 firms which make decisions individually. The decision-making strategy for different sizes of firms is also displayed in table 9.74.

There is no distinct pattern differentiating the decision-making strategies of small, medium and large sized firms as observed in table 9.74. However, most firms employed group decision-making. This was confirmed by the contractors during the personal interviews.

Table 9.73 : Comparison of mean scores of tender adjudication factors by position of respondent

S/NO	TENDER ADJUDICATION FACTORS	MEAN SCORES OF RATINGS	
		DIRECTORS	ESTIMATORS
1	Accuracy of cost estimate	6.33	6.35
2	Credit worthiness of client	5.83	6.00
3	Contractual liabilities	5.83	5.65
4	Type of job	5.83	5.06
5	Relationship with consultants	5.47	5.65
6	Relationship with client	5.27	5.83
7	Work load commitment of contractor	5.30	5.35
8	Complexity of work	5.38	5.18
9	Size of job	5.43	5.00
10	Amendments to standard form	5.14	5.35
11	Management and expertise availability	5.14	5.24
12	Contract period	5.20	4.88
13	Job location	5.13	4.71
14	Number of bidders	5.25	4.13
15	Type of contract	4.57	4.65
16	Material, plant and labour availability	4.53	4.35
17	Identity of bidders	4.53	3.41
18	Proportion of priceable builder's work	4.13	4.06
19	Proportion of preliminaries	4.00	4.06
20	Economic conditions (job availability)	3.97	4.00
21	Inflation	3.86	4.06
22	Proportion of domestic sub-contractor's work	3.66	3.82
23	Proportion of NSC/suppliers' work	3.69	3.65
24	Financial availability of contractor	3.89	3.29
25	Technological conditions	3.72	3.35
26	Scope for claims	3.27	3.29
27	Political conditions	2.53	2.94

Figure 9.31 : Minitab LPLOT and TWO-WAY ANOVA of mean rating scores of tender adjudication factors by position of respondent



TWO-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
FACTORS	26	43.5286	1.6742
POSITION	1	0.2364	0.2364
ERROR	26	2.2019	0.0847
TOTAL	53	45.9669	

(Note : Tender adjudication factors are arranged according to table 9.67)

Figure 9.32 : Decision-making strategy of contractors

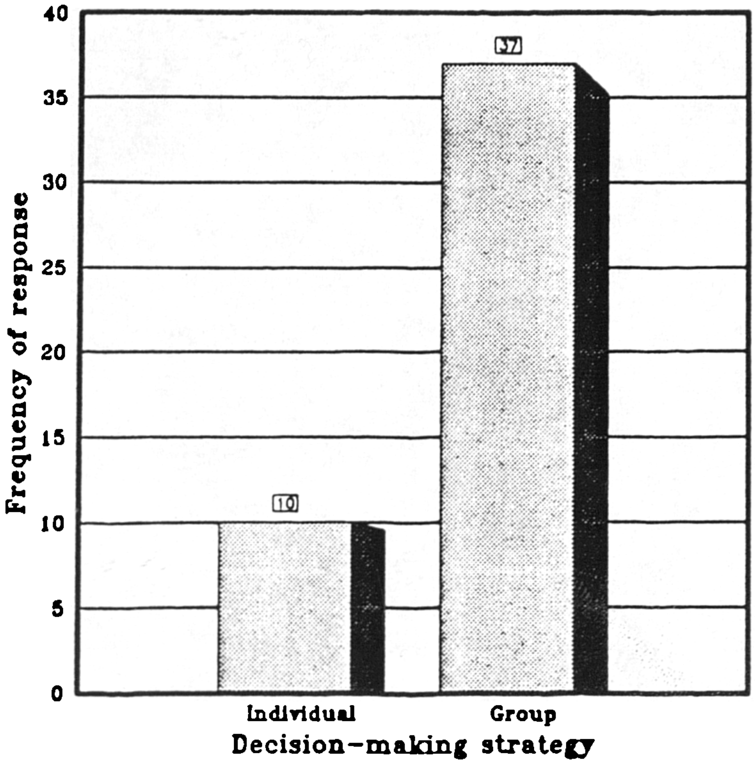


Table 9.74 : Decision-making strategy for different sizes of firm

FIRM SIZE	DECISION-MAKING STRATGEY	
	Individual	Group
Small	2	11
Medium	4	11
Large	4	15

(h) Pricing difficulties of different job types

In an attempt to investigate the financial risks involved in pricing different types of job, contractors were requested to rank the order of pricing difficulties they have experienced for eight different categories of refurbishment jobs. A concordance test was performed using Kendall's Coefficient of Concordance to determine whether there is general agreement in the order of ranking (job types) among contractors. The SPSS-X computer output is shown in Table 9.75. This test was performed on only 42 out of the 47 contractors as five contractors have not responded to this question. The observed significance level (probability-value) is approximately 0. Therefore, we have very strong statistical evidence that there is a high degree of concordance among contractors in the order of ranks for different job types. The 8 job categories are listed in order of pricing difficulties as shown in table 9.76.

Table 9.75 : Kendall's Coefficient of Concordance test

KENDALL COEFFICIENT OF CONCORDANCE

MEAN RANK	VARIABLE	
4.57	TRANS	Transport and utility
6.86	INDUS	Industrial
5.60	OFFICE	Office and Administration
2.70	HEALTH	Health and welfare
3.40	REFRESH	Entertainment and refreshment
3.01	RELIG	Religious
4.02	EDUC	Education
5.83	RESD	Residential

CASES	W	CHI-SQUARE	D.F.	SIGNIFICANCE
42	.3687	108.3974	7	.0000

Health and welfare buildings have been ranked as most difficult to price in refurbishment contracts. This could be ascribed to the relatively high proportion of complex services in these buildings especially in hospitals. Furthermore, these premises are also more sensitive to noise and dust pollution. Contractors undertaking such work often find it extremely difficult to estimate the cost of providing the necessary protective measures. This problem is further aggravated especially when the project has to be carried out in work phases in occupied buildings. As remarked by one contractor:-

"It is difficult to ascertain the amount of man-hours needed to keep these premises clean and free from noise disturbances during construction."

Table 9.76 : Ranking of job types in order of pricing difficulties

S/NO	TYPES OF JOBS	RANK	MEAN RANK	STD DEV
1	Health and Welfare	1	2.64	1.76
2	Religious	2	2.98	1.97
3	Refreshment and Recreation	3	3.36	1.67
4	Education, Scientific and Information	4	3.98	1.47
5	Transport and Utility	5	4.52	2.08
6	Administration and Office	6	5.45	1.74
7	Residential	7	5.74	2.13
8	Industrial	8	6.74	1.88

(Note: Rank 1 = most difficult and Rank 8 = least difficult)

Furthermore, the difficulty of pricing health and welfare buildings is well reflected in the high tender bid variability as measured by the relative dispersion of bids (RD). The statistical analysis of 2261 refurbishment contracts produces a mean RD of 11.01% for health and welfare buildings which is much higher than other categories of job type (as shown in table 9.7).

The main problems faced in the pricing of refurbishment work for religious buildings lie in the estimation of labour hours of skilled craftsmen. This kind of work (mainly traditional Victorian churches) entails highly skilled labour which is costly and scarce in the present market conditions. The restoration of such buildings also involves much higher financial risks to the contractor as the condition of buildings is often difficult to assess. This is true especially for timber work and ornamental fittings which may sometimes conceal dry rot.

The refurbishment of refreshment and recreational buildings is normally carried out while they are occupied as most clients prefer to continue business activities during construction. The renovation of such premises is usually executed in phases. Under such circumstances, contractors must provide additional noise, dust and safety protective measures which may be difficult to price. Besides this, the phasing of work impairs productivity of work force and plant. It also causes many problems in the co-ordination and supervision of work. The effect on the disruption of productivity due to the above factors is difficult to foresee and measure. Furthermore, the moving of labour, materials and plant between different parts of the building may affect the progress of work. Depending on the occupants, sometimes contractors may face court injunctions to stop work during certain hours. The difficulty in ascertaining the sensitivity and tolerance level of the occupants is well emphasised by one contractor as follows:-

"We really do not know how the occupants will react. In one case, we were asked to stop work because occupants in the other parts of the building could not bear the smell of paint arising from the work section."

Most contractors tend to agree that the refurbishment of industrial buildings are relatively simple and straightforward. This is indicated by the relatively low RD of tender bids of 9.29% as shown in table 9.7. The main reason is that such work is usually carried out in large and spacious vacated buildings and does not involve many trades and complicated services. These jobs are also mainly located outside London in less congested sites thereby reducing accessibility problems.

9.7.1.2 Risk management of contractors

(a) Ranking of construction risk factors (financial risk)

Table 9.77 provides a list of construction risk factors commonly encountered by contractors in refurbishment work. The factors are ranked in decreasing order according to the level of financial risks involved. Accessibility of work and productivity of work force and plant emerged as the most pertinent risk factors. There is also general consensus among contractors in the assessment of these two factors as reflected by the low standard deviations of the mean scores (1.32 and 1.28 respectively). Furthermore, the mean scores are not so spread out as compared to those tender adjudication factors as shown in table 9.67.

Due to the inherent nature and characteristics of refurbishment work which is normally carried out indoors, limitation of access is a common phenomenon. Restriction of access has dramatic impact on the productivity of labour and plant as explained before. It also affects the choice of plant and storage of materials. As a result, more provisions need to be made for in congested sites.

On the other hand, refurbishment work is usually not adversely affected by weather conditions as it is normally performed in existing buildings (especially if work is carried out indoors). This relatively low exposure to weather conditions risk is clearly reflected in the low mean score of 2.91 as shown in table 9.77. Progress of work is normally not disrupted by weather except for work involving the refurbishment of external facade of building or re-roofing.

Table 9.77 : Ranking of construction risk factors

RANK	CONSTRUCTION RISK FACTORS	MEAN SCORE	STD DEV	SKEWNESS	KURTOSIS
1	Accessibility of work	5.15	1.32	-0.64	-0.15
2	Productivity of work force and plant	5.00	1.28	-0.07	-0.60
3	Restriction on working hours	4.87	1.73	-0.41	-0.81
4	Storage and handling of materials	4.84	1.57	-0.25	-1.05
5	"Matching up" of refurbished work with existing work	4.70	1.63	-0.19	-0.84
6	Programming of work	4.67	1.49	-0.77	0.51
7	Noise and dust protection	4.66	1.36	-0.71	1.08
8	Supervision and co-ordination of work force	4.62	1.50	-0.03	-0.91
9	Protection of existing building	4.60	1.50	-0.44	-0.08
10	Removal of rubbish and debris	4.52	1.46	-0.41	-0.36
11	Security	4.48	1.60	0.11	-0.62
12	Selection of labour	4.47	1.36	-0.30	-0.06
13	Protection of occupants/passer-by	4.13	1.69	0.24	-0.59
14	Weather conditions	2.91	1.59	0.88	0.44

(b) Common risk management strategy adopted by contractors

Question 5 in the survey questionnaire provides an indication of the common risk management strategies employed by contractors in competitive bidding. Four main categories of risk management strategies were listed and contractors were asked to rate the frequency of use of various strategies. The ranking of various types of risk management strategies based upon their respective mean rating scores is displayed in table 9.78. Thus, it was observed that there are three main types of risk management strategies commonly adopted by contractors in competitive tendering for refurbishment work. They are namely;

(i) risk reduction through information gathering, (ii) risk reduction through qualification of tender, and (iii) risk retention through provision of risk allowance in tender. The least frequently used strategy is risk retention where contractors make no risk provision in their tender. This view is shared by most contractors as indicated by the extremely low standard deviation of the mean score (0.95). There is also general consensus on the risk avoidance strategies (standard deviation = 1.38 and 1.39) as shown in table 9.78.

Table 9.78 : Risk management strategies of contractors

S/NO	RISK MANAGEMENT STRATEGIES	RANK	MEAN RANK	STD DEV
1	Risk reduction - Reduce risk through information gathering	1	5.26	1.41
2	Risk reduction - Qualifying tender documents	2	5.06	1.66
3	Risk retention - Provision of risk allowance in tender	3	4.96	1.50
4	Risk transfer - Transferring risks to sub-contractors	4	3.87	1.78
5	Risk transfer - Taking up insurance polices	5	2.41	1.51
6	Risk avoidance - Pricing uncompetitive bid (cover bid)	6	2.15	1.38
7	Risk avoidance - Return tender documents unpriced	7	2.02	1.39
8	Risk retention - Taking all risks without any provisions	8	1.49	0.95

(Note : Rank 1 = Most frequently adopted and Rank 7 = Least frequently adopted)

Thus, as illustrated in table 9.78, most refurbishment contractors utilised information search as a risk reduction strategy in managing risks in competitive tendering. In practice, there are several sources of information which are frequently used by contractors as follows:-

i) Tender documentation.

ii) Enquiries from clients and consultants.

iii) Site visit.

iv) Contractor's own records.

v) Published cost and price data.

vi) Sub-contractors' and suppliers' quotations.

vii) Independent organisations (for example, Builders' Conference).

viii) Other informal sources such as grapevine information.

9.7.1.3 General information of firm

The turnover in refurbishment work for all the forty-seven contractors is shown in figure 9.33. About 50% (28 contractors) of the contractors have turnovers of less than £20m. Only 3 large firms have a turnover of over £70m.

The median tender success rate of firms in competitive bidding is about 20% (1 in 4 jobs) as shown in figure 9.34. It is also noted that a large proportion of contractors (41 contractors) performed tender analysis to monitor both their bidding performance and the performance of their respective competitors as displayed in figure 9.35. The main sources of information commonly used by contractors to conduct tender appraisal are listed in table 9.79. Most firms rely on independent organisation such as the Builders' Conference or their own tender records to obtain the necessary information to audit their bidding performance.

Figure 9.33 : Turnover of firms (refurbishment work)

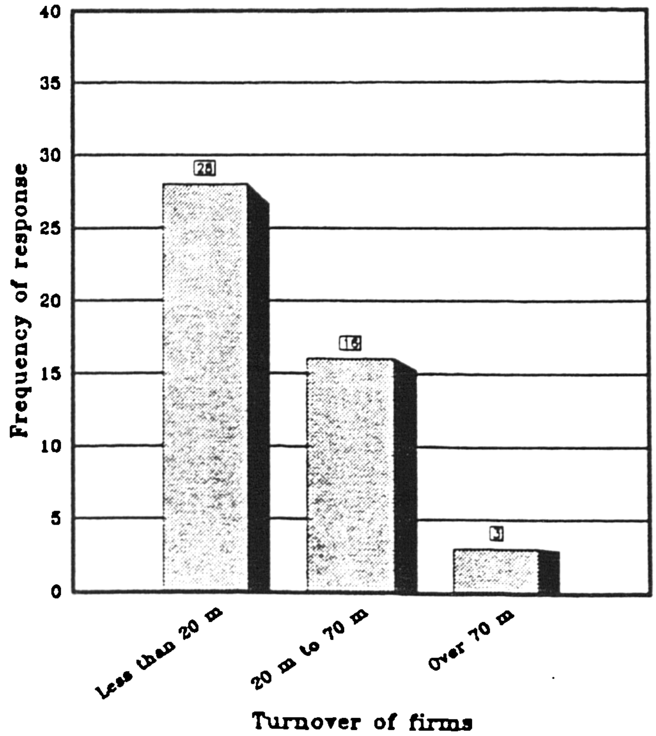


Figure 9.34 : Tender success rate of firms (refurbishment work)

```
SUCCESS   Success rate of firm

     COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY   .40 OCCURRENCES

       1          0  ***
       1          5  ***
       7         10  *****************
       7         15  *****************
      13         20  ********************************
      11         25  ***************************
       5         30  ************
       0         35
       0         40
       0         45
       0         50
       0         55
       0         60
       0         65
       0         70
       0         75
       0         80
       0         85
       0         90
       0         95
       2        100  *****
                     I....+....I....+....I....+....I....+....I....+....I
                     0         4         8        12        16        20
                                  HISTOGRAM FREQUENCY

MEAN          22.553     STD ERR        2.573     MEDIAN       20.000
MODE          20.000     STD DEV       17.637     VARIANCE    311.079
KURTOSIS      14.406     S E KURT        .681     SKEWNESS      3.576
S E SKEW        .347     RANGE         98.000     MINIMUM       1.000
MAXIMUM       99.000     SUM         1060.000

VALID CASES       47     MISSING CASES      0
```

Figure 9.35 : Response rate of contractors who perform tender analysis

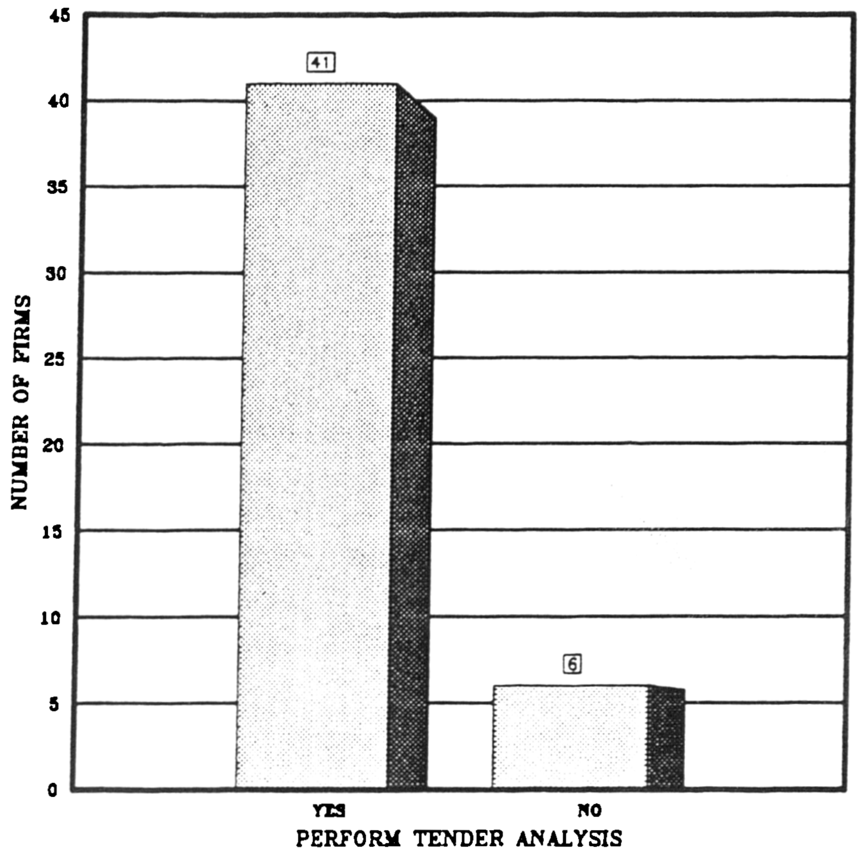


Table 9.79 : Information sources for monitoring bidding performance

S/NO	INFORMATION SOURCES	RANK	MEAN RANK	STD DEV
1	From independent organisation (eg Builders' Conference)	1	5.17	2.06
2	From past tender bids	2	4.43	1.92
3	From informal contact with competitors	3	3.80	1.70
4	Grapevine information	4	3.78	1.77

9.7.2 Analysis of Repertory Grid data

As discussed in chapter four, there are five main analytical techniques commonly adopted for the analysis of grid data namely: (i) Frequency analysis, (ii) Content analysis, (iii) Visual focusing, (iv) Principal Component analysis, and (v) Cluster analysis. In this section, the results of each analysis will be presented highlighting the main findings of the Repertory Grid Interview. Only four of the five techniques were adopted to analyse the fully rated grid data as visual focusing is only used on raw grid with ticks and crosses rather than a rated grid.

9.7.2.1 Frequency analysis of grid

(a) Frequency analysis of free-response constructs

The main purpose of the frequency counts analysis is to identify risk perception constructs which are frequently mentioned by those contractors (directors and estimators) which were interviewed. As shown in table 9.80, the frequency counts analysis of the full grid data shows that the free-response risk perception constructs of the twenty-two contractors interviewed are wide ranging. A total of 89 constructs have been elicited from the group of contractors. This comprises 36 different types of risk perception constructs of the contractors.

Although, most contractors often claim that there are innumerable factors which must be considered when assessing the risk involved in any particular bidding situation and that each bidding situation is unique, this result provides evidence that only certain factors are significant. Based upon the frequency analysis, only a few constructs appear to be frequently utilised by the contractors in discriminating between high risk and low risk bidding situations. The more commonly adopted constructs include: (i) intensity of work, (ii) tender documentation (Bills of Quantities), (iii) occupation of building, and (iv) noise and/or dust protection.

Table 9.80 : Frequency analysis of free-response risk perception constructs of contractors

S/NO	BIPOLAR DIMENSIONS OF CONSTRUCTS		FREQUENCY
1	Good documentation (BQ)	Poor documentation	9
2	Low intensity of work	High intensity of work	8
3	Vacant building	Occupied building	8
4	No or little noise and dust protection	Lots of noise and dust protection	7
5	No protection of existing building	Protection of existing building	5
6	Low vandalism/security	High vandalism/security	4
7	Reasonable contract period	Unreasonable contract period	4
8	No public protection	Public protection	3
9	Standard contract form	Modified contract form	3
10	Low liquidated damages	High liquidated damages	3
11	No protection of listed building and expensive items	Protection of listed building and expensive items	3
12	Low degree of temporary work	High degree of temporary work	2
13	No structural work	Lots of structural work	2
14	Good quality of design information	Poor quality of design information	2
15	Low degree of demolition work	High degree of demolition work	2
16	Single phase work	Working in multiple phases	2
17	No restriction on working hours	Restriction on working hours	2
18	Vacant domestic building	Occupied domestic building	2
19	Low quality requirement	High quality requirement	1
20	No collateral warranty	Presence of collateral warranty	1
21	Timely start of project	Delay start of project	1
22	No protection of new work	Protection of new work	1
23	Clear specification of work hours	Unclear specification of work hours	1
24	High competence of consultant	Low competence of consultant	1
25	Good buildability	Poor buildability	1
26	Low complexity of own work	High complexity of own work	1
27	Low proportion of own labour	High proportion of own labour	1
28	Low complexity of sub contract work	High complexity of sub contract work	1
29	Low percentage of retention	High percentage of retention	1
30	Low degree of ground work	High degree of ground work	1
31	Non commercial client	Commercial client	1
32	Internal refurbishment	External refurbishment	1
33	Familiar work	Unfamiliar work	1
34	High percentage of new work	Low percentage of new work	1
35	Disinterested client	Fussy client	1
36	Low percentage of specialist work	High percentage of specialist work	1
	TOTAL		89

The main reasons as provided by the contractors for adopting the above constructs are described as follows:-

a) **Intensity of work** - The intensity of work refers to the value of work which must be carried out per week or per month. It is normally determined by dividing the contract value (tender sum) by the contract period. Most contractors desire to tender for contracts with high intensity in order to achieve their targeted turnover. High intensity contracts usually demand a large input of resources from the contractors within a short period and thus would normally impose higher risks on contractors. While jobs of lower intensity are usually less risky in nature.

b) **Documentation (BQ)** - The presentation and clarity of documentation namely the Bills of Quantities has undue influence on the risk perception of contractors. Inadequate and badly structured bills can cause much difficulty to estimators in the pricing of work. This problem is further aggravated when the bill is badly structured thereby increasing the risks of misinterpretation or omission of items. Thus, the extent and clarity in which information is provided to the contractors has undue influence on their risk assessment. This point is well emphasised by one refurbishment specialist who commented:-

"We do not want a chunk of papers (bills of quantities) to confuse us.....What we need is a simple, concise and well-structured document to enable us to appreciate the kind of work we will be committing..."

c) **Noise and/or dust protection** - A large proportion of refurbishment work is normally carried out in city areas. Furthermore, they are often either carried out in occupied buildings or in vacant buildings with surrounding occupied buildings. Consequently, the problem of providing adequate measures to reduce noise and dust is highly complicated. Very often, the amount of protection required is dependent upon the tolerance level of the occupants. As a result, consultants find much difficulty in determining and specifying these protective measures thus resulting in contractual disputes at a later stage. Contractors frequently have to rely on their experience from past projects in various locations to estimate the extent of noise and dust protection required for the proposed contract. However, their estimates could sometimes be wrong thus causing much disruption to work and financial losses. From the interview of contractors, it was found that most contractors tend to agree that occupants of commercial and industrial buildings have a relatively higher tolerance level (with respect to noise and dust disturbances) as compared to those in domestic and hospital premises.

d) **Occupation of building** - The main difficulties involved in refurbishing an occupied buildings are (i) liabilities to injury to third party (ii) restriction in movement of both materials, plant and labour, and (iii) organisation and productivity of work force. Ideally, contractors would prefer to work in vacant buildings thus avoiding the above mentioned risks. However, in practice, many clients particularly commercial client, prefer to resume their business operations while refurbishment work is in progress.

(b) Frequency analysis of pre-determined constructs

Similarly, a frequency analysis was performed on the pre-determined constructs of the contractors. As shown in table 9.81, there is a total of 120 pre-determined constructs elicited from the twenty-two refurbishment contractors. A visual inspection of the frequency count shows that there are five constructs which are frequently utilised by contractors in distinguishing between high and low risk bidding situations as described below.

1) **Degree of difficulty of pricing the cost estimate** - The accuracy of the cost estimate is of vital importance in enabling the contractor to secure the proposed contract and make a profit. Generally, the accuracy of cost estimate is affected by a number of factors such as the clarity of tender documentation, availability and accuracy of cost information and the experience and skills of the estimator. In this study, the degree of pricing difficulty is used as a measure to indicate the accuracy of the cost estimate. Both the researcher and the interviewee shared similar understanding that a contract which is difficult to price is one that has low accuracy

and high risk and vice versa.

2) **Client relationship** - The relationship between the client and the contractor is of paramount importance for reasons such as smooth and rapid payment of work and repeat work. With good client relationship, contractors are able to work smoothly and keep up with the agreed construction programme. Many large and medium sized firms place more emphasis in selecting jobs with good client relationships. In the present competitive market, these firms usually wish to establish good rapport with clients so as to secure future contracts either through selective tendering or negotiated contracts.

3) **Access** - Working in congested or restricted sites is common in refurbishment work especially in city areas. Restricted access poses many problems to contractors such as restricting the movement of materials and workers, storage of materials and the choice of plant. The main impact of restricted sites is on the productivity of plant and labour which most estimators find it difficult to judge and allow for appropriate provisions in the tender.

4) **Complexity** - Most refurbishment work is usually complicated in nature particularly when it involves structural alterations and renovation of complex services. However, different contractors perceive risks in complexity differently depending on their management expertise and experience. What may seem to be a complex job to one contractor may be viewed as a relatively straightforward by another contractor. Generally, refurbishment specialists prefer to tender for complex and high risk jobs. The reason being such jobs are usually less competitive and more profitable. Besides this, they also provide much challenge and motivation to both the estimating and site staff of the company. From the interview, it was found that most refurbishment contractors are competent to perform a reasonable range of contracts. Normally, it is the availability of manpower at the time of tendering that determines whether the contractor is keen on the particular job. This point is well emphasised by one contractor as follows:-

"We are capable of refurbishing most types of work. But, most of the time we are constrained by the availability of resources (whether there is a right person available to manage the job) more than the nature of the work."

5) **Consultant relationship** - As in client relationship, most contractors think that good consultant relationship contributes much to the success of a project. A cordial and co-operative relationship must be established in order to facilitate good progress of the proposed work. Through the years, most contractors have mentally 'compiled' a list of consultants which he had worked with. Each individual contractor has a unique list of consultants which he would prefer to work with. Very often, this knowledge of past experiences with consultants provides the necessary guidelines to support the decision of contractors when tendering. However, sometimes due to various reasons such as good relationship with client or low workload, contractors may bid for projects where consultant relationship is not so preferable. Under such circumstances, contractors would make certain provisions in the tender bid by means of contingency or risk allowance.

Table 9.81 : Frequency analysis of pre-determined risk perception constructs of contractors

S/NO	BIPOLAR DIMENSIONS OF CONSTRUCTS		FREQUENCY
1	Easy cost estimate	Difficult cost estimate	20
2	Good client relationship	Poor client relationship	20
3	Easy access	Restricted access	18
4	Low complexity	High complexity	18
5	Good consultant relationship	Poor consultant relationship	18
6	High client credit	Low client credit	10
7	High workload	Low workload	10
8	Few bidders (less than or equal to 4)	Many bidders	2
9	Small size job	Large size job	2
10	Known identity of bidders	Unknown identity of bidders	2
	TOTAL		120

Thus, from the frequency counts analysis of both the free-response and pre-determined constructs, there are several constructs which appear to contribute more significantly in assisting contractors to discriminate high and low risk bidding situations. Table 9.82 provides a list of the more frequently adopted constructs together with the preference of high low risk poles of each construct by the contractors. The more frequently adopted constructs are listed as follows:-

i) Intensity of work.
ii) Tender documentation (Bills of quantities).
iii) Occupation of building.
iv) Noise and/or dust protection.
v) Degree of difficulty of pricing the cost estimate.
vi) Client relationship.
vii) Consultant relationship.
viii) Access.
ix) Complexity of work.

Table 9.82 : Frequency analysis of preferences for most frequent constructs

S/NO	HIGH RISK CONSTRUCT POLES	FREQUENCY OF OCCURRENCES		
		PREFER	NEUTRAL	DO NOT PREFER
1	High intensity of work	7	0	1
2	Poor documentation	0	0	9
3	Occupied building	2	0	6
4	Severe noise and dust protection	0	2	5
5	Difficult cost estimate	3	4	13
6	Poor client relationship	0	0	20
7	Poor consultant relationship	0	0	18
8	Restricted access	3	5	10
9	High complexity	9	4	5

9.7.2.2 Content analysis of grid

The content analysis enables the comparison of constructs for different categories of elements or constructs. Elements (bidding situations), constructs or the respondents may be grouped into various categories with respect to their similarities in content area. For example, bidding situations may be grouped into high or low risk situations so that frequency analysis may be performed to determine the distribution of risk perception of construct for high and low risk situations.

(a) Analysis of risk perception constructs by size of firm

Table 9.83 provides a comparison of risk perception constructs between small, medium and large sized construction firms. There are no discernible patterns or trends observed in the three groups of firms although it seems that both small and large firms employed the intensity of work and documentation constructs more frequently. This could be attributable to the size of job undertaken and the experience of both small and large sized firms. Small firms are generally less experienced and would normally tender for small contracts as constrained by their capability and capacity. They would normally tender for jobs of lower intensity (less than £30,000 per week). Jobs at the lower end of the market (less than £500,000) are also relatively more competitive as there are many firms eligible to undertake such work. Furthermore, most small jobs are of short duration. The contract documents are usually prepared by small and inexperienced consultancy firms which may sometimes produce poor documentation. Thus, the quality of documentation coupled with the limited experience of the firms have undue influence on the risk perception of small refurbishment contractors.

On the other hand, large contractors are usually more keen to tender for jobs of higher intensity (over £50,000 per week) so as to achieve their targeted turnover and recoup their high overheads. They have many more capabilities and a larger capacity to tender for a wide range of contracts. Most large firms would prefer to tender for larger and more complex projects. But refurbishment contracts of this job range are usually highly complicated and thus tender documentation may be onerous. As such, intensity of work and tender documentation have significant influence on the risk perception of these contractors.

(b) Analysis of risk perception constructs by specialism of firm

A comparison of frequency and type of constructs elicited from both the specialist and general refurbishment contractors reveals subtle differences between them as illustrated in table 9.84. Constructs from specialist contractors tend to be wide ranging and of a more complicated job nature. 140 constructs were elicited out of a list of 39 different constructs (both free response and pre-determined constructs) from 15 specialist firms. While the general contractors provided a total of 69 constructs out of 29 different constructs. A close examination of the nature of constructs of both types of firms shows that specialist firms are more concerned with the nature of job in their risk assessment. This could be due to the relatively more complex projects which they are usually involved in. Conversely, general contractors tend to tender for less complicated jobs and thus do not adopt any these constructs (related to job complexity) in their risk assessment.

Although there are some differences in the characteristics of risk perception constructs between refurbishment specialists and general contractors, they do share some common constructs in discriminating between high and low risk bidding situations as described below:-

(A) **Free response constructs**

- i) Intensity of work.
- ii) Documentation.
- iii) Occupation of building.
- iv) Noise and dust protection.

(B) **Pre-determined constructs**

- i) Cost estimate.
- ii) Client relationship.
- iii) Access.
- iv) Complexity.
- v) Consultant relationship.

Table 9.83 : Comparison of risk perception constructs by size of firm

S/NO	CONSTRUCTS	FREQUENCY OF OCCURRENCES		
		Small firm	Medium firm	Large firm
	(A) Free-response constructs			
1	Documentation (BQ)	3	1	5
2	Intensity of work	4	2	2
3	Occupation of building	1	4	3
4	Noise and dust protection	1	2	4
5	Protection of existing building	1	0	4
6	Vandalism/Security	2	0	2
7	Contract period	1	0	3
8	Public protection	1	0	2
9	Standard contract form	0	1	2
10	Liquidated damages	0	2	1
11	Protection of listed building/expensive items	0	2	1
12	Degree of temporary work	1	1	0
13	Degree of structural work	0	1	1
14	Quality of design information	1	1	0
15	Degree of demolition work	1	1	0
16	Work phase	0	1	1
17	Restriction on working hours	0	1	1
18	Vacant domestic building	2	0	0
19	Quality requirement	0	0	1
20	Collateral warranty	0	0	1
21	Timely start of project	1	0	0
22	Protection of new work	0	0	1
23	Clear specification of work hours	0	1	0
24	Competence of consultant	0	1	0
25	Buildability	1	0	0
26	Complexity of own work	1	0	0
27	Proportion of own labour	1	0	0
28	Complexity of sub contract work	1	0	0
29	Percentage of retention	1	0	0
30	Degree of ground work	0	1	0
31	Commercial client	0	1	0
32	Internal external refurbishment	1	0	0
33	Familiarity of work	0	0	1
34	Percentage of new work	0	1	0
35	Disinterested fussy client	0	1	0
36	Percentage of specialist work	1	0	0
	TOTAL	27	26	36

S/NO	CONSTRUCTS	FREQUENCY OF OCCURRENCES		
		Small firm	Medium firm	Large firm
	(B) Pre-determined constructs			
1	Cost estimate	7	6	7
2	Client relationship	7	6	7
3	Access	6	7	5
4	Complexity	5	6	7
5	Consultant relationship	7	5	6
6	Client credit	4	4	2
7	Workload	5	2	3
8	Number of bidders	1	1	0
9	Job size	1	0	1
10	Identity of bidders	1	0	1
	TOTAL	44	37	39

Table 9.84 : Comparison of risk perception constructs by specialism of firm

S/NO	CONSTRUCTS	FREQUENCY OF OCCURRENCES	
		Specialist firms	General firms
	(A) Free-response constructs		
1	Documentation (BQ)	6	3
2	Intensity of work	5	3
3	Occupation of building	6	2
4	Noise and dust protection	5	2
5	Protection of existing building	4	1
6	Vandalism/Security	3	1
7	Contract period	2	2
8	Public protection	1	2
9	Standard contract form	3	0
10	Liquidated damages	3	0
11	Protection of listed building/expensive items	3	0
12	Degree of temporary work	1	1
13	Degree of structural work	1	1
14	Quality of design information	1	1
15	Degree of demolition work	1	1
16	Work phase	2	0
17	Restriction on working hours	2	0
18	Vacant domestic building	1	1
19	Quality requirement	0	1
20	Collateral warranty	1	0
21	Timely start of project	0	1
22	Protection of new work	1	0
23	Clear specification of work hours	0	1
24	Competence of consultant	1	0
25	Buildability	1	0
26	Complexity of own work	1	0
27	Proportion of own labour	1	0
28	Complexity of sub contract work	1	0
29	Percentage of retention	1	0
30	Degree of ground work	1	0
31	Commercial client	1	0
32	Internal external refurbishment	0	1
33	Familiarity of work	0	1
34	Percentage of new work	1	0
35	Disinterested fussy client	1	0
36	Percentage of specialist work	0	1
	TOTAL	62	27

S NO	CONSTRUCTS	FREQUENCY OF OCCURRENCES	
		Specialist firms	General firms
	(B) Pre-determined constructs		
1	Cost estimate	14	6
2	Client relationship	13	7
3	Access	13	5
4	Complexity	12	6
5	Consultant relationship	11	7
6	Client credit	7	3
7	Workload	6	4
8	Number of bidders	1	1
9	Job size	1	1
10	Identity of bidders	0	2
	TOTAL	78	42

(c) Analysis of risk perception constructs by position of respondent

Table 9.85 displays the different risk perception constructs provided by both the directors and estimators of the firms. There appears to be no discernible difference in the nature and distribution of the elicited constructs. Logically, it would be expected that estimators will be more concerned with estimating and construction risks while directors would pay more attention on the general aspects of risks involved in a project such as economic conditions, competitive pressures, inflation, client and consultant relationship. However, the distribution of constructs as shown in table 9.85 does not reveal any difference in the characteristic of constructs between directors and estimators. Thus, based upon the content analysis of constructs, there appears to be no distinction in the risk perception of directors and estimators.

(d) Content analysis of elements (bidding situations) by client type

In conducting the content analysis of the elements (bidding situations), the characteristics of both the high and low risk bidding situations were grouped into different categories such as job type, client type, job size and location (Table 9.86). The purpose of this analysis is to determine whether high or low risk bidding situations possess any unique or specific job characteristics. For instance, the elements may be classified into different job types so that frequency analysis may be performed to determine the number of high or low risk bidding situations in each job type category.

Besides this, Chi-square and Contingency table tests were conducted on each category. The main objective of these tests is to determine whether the proportion of high and low risk elements are the same for different categories of job characteristics.

Table 9.85 : Comparison of risk perception constructs by position of respondent

S/NO	CONSTRUCTS	FREQUENCY OF OCCURRENCES	
		Estimators	Directors
	(A) Free-response constructs		
1	Documentation (BQ)	7	2
2	Intensity of work	6	2
3	Occupation of building	5	3
4	Noise and dust protection	4	3
5	Protection of existing building	4	1
6	Vandalism/Security	2	2
7	Contract period	2	2
8	Public protection	3	0
9	Standard contract form	3	0
10	Liquidated damages	3	0
11	Protection of listed building/expensive items	2	1
12	Degree of temporary work	2	0
13	Degree of structural work	2	0
14	Quality of design information	1	1
15	Degree of demolition work	1	1
16	Work phase	2	0
17	Restriction on working hours	2	0
18	Vacant domestic building	0	2
19	Quality requirement	1	0
20	Collateral warranty	1	0
21	Timely start of project	1	0
22	Protection of new work	1	0
23	Clear specification of work hours	1	0
24	Competence of consultant	1	0
25	Buildability	0	1
26	Complexity of own work	0	1
27	Proportion of own labour	0	1
28	Complexity of sub contract work	0	1
29	Percentage of retention	0	1
30	Degree of ground work	0	1
31	Commercial client	1	0
32	Internal external refurbishment	0	1
33	Familiarity of work	0	1
34	Percentage of new work	1	0
35	Disinterested fussy client	1	0
36	Percentage of specialist work	1	0
	TOTAL	61	28

S/NO	CONSTRUCTS	FREQUENCY OF OCCURRENCES	
		Estimators	Directors
	(B) Pre-determined constructs		
1	Cost estimate	14	6
2	Client relationship	12	8
3	Access	13	5
4	Complexity	13	5
5	Consultant relationship	11	7
6	Client credit	8	2
7	Workload	6	4
8	Number of bidders	2	0
9	Job size	2	0
10	Identity of bidders	0	2
	TOTAL	81	39

Table 9.86 : Characteristics of elements (bidding situations)

CHARACTERISTICS OF ELEMENTS	FREQUENCY OF OCCURRENCES	
	HIGH RISK ELEMENTS	LOW RISK ELEMENTS
A) JOBTYPE		
1) Transport and Utility	2	4
2) Industrial	2	4
3) Office	26	23
4) Health and Welfare	7	3
5) Recreation and Refreshment	11	5
6) Religious	0	1
7) Education, Scientific and information	4	11
8) Residential	13	15
B) CLIENT TYPE		
1) Public	6	12
2) Private	60	54
C) JOBSIZE		
1) Less than £100,000	2	4
2) £100,000 to £250,000	6	6
3) £250,000 to £500,000	12	13
4) £500,000 to £750,000	8	11
5) £750,000 to £1,000,000	7	9
6) £1,000,000 to £1,250,000	5	3
7) £1,250,000 to £1,500,000	2	4
8) £1,500,000 to £1,750,000	3	0
9) £1,750,000 to £2,000,000	6	6
10) £2,000,000 to £2,250,000	0	3
11) £2,250,000 to £2,500,000	1	0
12) £2,500,000 to £2,750,000	0	1
13) £2,750,000 to £3,000,000	0	0
14) More than £3,000,000	14	6
D) LOCATION		
1) London and Greater London	37	46
2) Outer London	19	10

The frequency counts of both high and low risk elements for different client types namely private and public were tabulated in table 9.87. A chi square value of 1.34 was computed. This is less than the chi square value (3.84 at the 5% significance level and one degree of freedom) obtained from the chi square distribution table (appendix F). Thus, there is no difference in the proportion of high and low risk elements between different client types.

Table 9.87 : Chi-square test of elements by client type

ELEMENTS / CLIENT TYPE	HIGH RISK ELEMENTS	LOW RISK ELEMENTS
Public	6	12
Private	50	54

MINITAB OUTPUT

```
Expected counts are printed below observed counts

        High Risk  Low Risk    Total

  1         6        12          18
         8.26      9.74

  2        50        54         104
        47.74     56.26

Total      56        66         122


ChiSq =  0.619 +  0.526 +
         0.107 +  0.091 = 1.343
df = 1
```

(d) Content analysis of elements by job location

Similarly, the chi square test of elements by job location produced a chi-square value of 3.77 as shown in table 9.88. This is less than the corresponding chi-square table value of 3.84 at the 5% significance level (appendix F). Thus, we confirm that there is no difference in the proportion of high and low risk elements for different job locations.

Table 9.88 : Chi-square test of elements by job location

ELEMENTS / JOB LOCATION	HIGH RISK ELEMENTS	LOW RISK ELEMENTS
London and Outer London	37	46
Outside London	19	10

MINITAB OUTPUT

```
Expected counts are printed below observed counts

      High Risk  Low Risk    Total

   1       37        46        83
        41.50     41.50

   2       19        10        29
        14.50     14.50

Total      56        56       112


ChiSq =  0.488 +  0.488 +
         1.397 +  1.397 = 3.769
df = 1
```

(e) **Content analysis of elements by job type**

The contingency table of elements by different job types as shown in table 9.89 produced a chi-square value of 9.36 with 5 degrees of freedom. Since 9.36 is lesser than 11.07 in the chi-square distribution table. We therefore also confirm that there is no difference in the proportion of high and low risk elements for different job types.

Table 9.89 : Contingency table test of elements by job type

ELEMENTS / JOB TYPE	HIGH RISK ELEMENTS	LOW RISK ELEMENTS
Office	26	23
Health and Welfare	7	3
Recreation and Refreshment	11	5
Education, Information and Scientific	4	11
Residential	13	15
Transport, Industrial and Religious	4	9
TOTAL	65	66

```
MINITAB OUTPUT

Expected counts are printed below observed counts

          High      Low     Total
          Risk      Risk

    1       26       23       49
         24.31    24.69

    2        7        3       10
          4.96     5.04

    3       11        5       16
          7.94     8.06

    4        4       11       15
          7.44     7.56

    5       13       15       28
         13.89    14.11

    6        4        9       13
          6.45     6.55

Total       65       66      131

ChiSq =  0.117 +  0.115 +
         0.837 +  0.825 +
         1.180 +  1.162 +
         1.592 +  1.568 +
         0.057 +  0.057 +
         0.931 +  0.917 = 9.359
df = 5
```

(f) Content analysis of elements by job size

The contingency table test of elements by job type produced a chi-square value of 4.23 as shown in table 9.90. This value is also lesser than the chi-square table value of 9.49 at the 5% significance level (degrees of freedom = 4). Therefore, we confirm that there is no difference in the proportion of high and low risk elements for different job sizes.

Table 9.90 : Contingency table test of elements by job size

ELEMENTS / JOB SIZE	HIGH RISK ELEMENTS	LOW RISK ELEMENTS
1) Less than £250,000	8	10
2) £250,000 to £500,000	12	13
3) £500,000 to £1,000,000	15	20
4) £1,000,000 to £3,000,000	24	26
5) Over £3,000,000	14	6
TOTAL	73	75

MINITAB OUTPUT

```
Expected counts are printed below observed counts

          High      Low     Total
          Risk      Risk

    1        8        10       18
          8.88      9.12

    2       12        13       25
         12.33     12.67

    3       15        20       35
         17.26     17.74

    4       24        26       50
         24.66     25.34

    5       14         6       20
          9.86     10.14

Total       73        75      148

ChiSq =  0.087 +  0.085 +
         0.009 +  0.009 +
         0.297 +  0.289 +
         0.018 +  0.017 +
         1.733 +  1.687 = 4.230
df = 4
```

Besides analysing the elements, content analysis was also performed to identify common characteristics among the elicited constructs of the contractors. From the analysis, it was found that risk perception constructs of directors and estimators in competitive tendering for refurbishment work may be broadly grouped into six categories (as shown in table 9.91) as follows:-

a) **Contract related constructs** - These constructs refer to the contractual liabilities and responsibilities imposed on the contractor by the client. They are normally written in the contract conditions or the specifications of the bills of quantities.

b) **Information related constructs** - These constructs are related to information sources both from inside and outside a construction firm. Provided information such as tender documentation, contractor's own cost data and information with regard to market conditions and competition are vital determinants in influencing the risk perception of contractors.

c) **Protection related constructs** - These constructs are concerned with protective measures required to ensure the safety of buildings and people during construction. These items of work are usually difficult to price because of varying subjective standards imposed by the clients and consultants.

d) **Personnel related constructs** - This category of constructs arises mainly due to public relations between the client, consultants and contractor. It also relates to the competence and personality of the three parties.

e) **Work content related constructs** - Constructs which describe the content of work fall into this category. These constructs define the scope of work and the extent of commitment needed of the contractor. They also describe the distribution of work (percentage of main contractor and sub-contractors' work) between the main contractor and sub-contractors.

f) **Work nature related constructs** - These constructs determine the difficulty and complexity of the project. They are usually associated with the type of building and the nature of work undertaken by the contractor.

Table 9.91 : Content analysis of risk perception constructs of contractors

CATEGORY	CONSTRUCTS
1) Contract related constructs	a) Contract form b) Liquidated damages c) Contract period d) Restrictions on working hours e) Quality requirements f) Collateral warranty g) Specification of work hours h) Percentage of retention
2) Information related constructs	a) Documentation (Bills of quantities) b) Design information c) Cost estimate d) Number of bidders e) Risk f) Identify of bidders
3) Protection related constructs	a) Noise and dust protection b) Public protection c) Protection of listed buildings and expensive items d) Security e) Protection new of work f) Protection of existing building
4) Personnel related constructs	a) Consultant relationship b) Competence of consultants c) Commercial client d) Familiar client e) Client relationship f) Client credit
5) Work content related constructs	a) Intensity of work b) Phase work c) Timely start of project d) Buildability e) Complexity of contractor's own work f) Proportion of contractor's own work g) Proportion of new work h) Complexity of sub-contract work i) Proportion of specialist work j) Size of job k) Work load of contractor l) Familiarity of work
6) Work nature related constructs	a) Occupation of building b) Degree of temporary work c) Degree of structural work d) Degree of demolition work e) Occupation of domestic building f) Degree of ground work g) Internal or External refurbishment h) Complexity of job i) Restriction of access

(g) Analysis of category of constructs by size of firm

Similarly, chi-square and contingency table tests were performed to determine whether the distribution of constructs (in their respective categories) are equal for different firm size, firm specialism and position of respondent. Tables 9.92 shows the distribution of various categories of constructs for small, medium and large sized firms. The chi square value obtained from the contingency table is 18.28. This value is slightly less than 18.31 obtained from appendix F at 10 degrees of freedom. Therefore, the null hypothesis is accepted and we conclude that the proportions in the 6 categories of constructs are similar for small, medium and large sized contractors. This result infers that the size of firm does not influence the risk perception of contractors in discriminating between high or low risk bidding situations.

Table 9.92 : Contingency table test of constructs by firm size

FIRM SIZE	CATEGORY OF CONSTRUCTS					
	CONTRACT RELATED	INFORMATION RELATED	PROTECTION RELATED	PERSONNEL RELATED	WORK CONTENT RELATED	WORK NATURE RELATED
Small	3	20	5	18	16	16
Medium	4	16	3	18	5	21
Large	7	20	13	15	10	12

```
MINITAB OUTPUT

Expected counts are printed below observed counts

            C1      C2      C3      C4      C5      C6   Total

    1        3      20       5      18      16      16      78
          4.92   19.68    7.38   17.92   10.89   17.22

    2        4      16       3      18       5      21      67
          4.23   16.90    6.34   15.39    9.36   14.79

    3        7      20      13      15      10      12      77
          4.86   19.42    7.28   17.69   10.75   17.00

Total       14      56      21      51      31      49     222

ChiSq =  0.749 + 0.005 + 0.767 + 0.000 + 2.396 + 0.086 +
         0.012 + 0.048 + 1.758 + 0.442 + 2.028 + 2.609 +
         0.947 + 0.017 + 4.486 + 0.409 + 0.053 + 1.468 = 18.279
df = 10
```

(h) Analysis of category of constructs by specialism of firm

Similarly, the contingency table test as shown in table 9.93 has a chi-square value of 0.58 which is much lesser than the chi-square distribution table value (11.07) at the 5% significance level and with 5 degrees of freedom. Thus, we confirm that there is no difference in the proportion of constructs for different specialism of firms.

Table 9.93 : Contingency table test of constructs by specialism of firm

FIRM SPECIALISM	CATEGORY OF CONSTRUCTS					
	CONTRACT RELATED	INFORMATION RELATED	PROTECTION RELATED	PERSONNEL RELATED	WORK CONTENT RELATED	WORK NATURE RELATED
Specialist	10	36	15	34	20	33
General	4	20	6	17	11	16

MINITAB OUTPUT

```
Expected counts are printed below observed counts

            C1      C2      C3      C4      C5      C6    Total

    1       10      36      15      34      20      33     148
          9.33   37.33   14.00   34.00   20.67   32.67

    2        4      20       6      17      11      16      74
          4.67   18.67    7.00   17.00   10.33   16.33

Total       14      56      21      51      31      49     222

ChiSq =  0.048 + 0.048 + 0.071 + 0.000 + 0.022 + 0.003 +
         0.095 + 0.095 + 0.143 + 0.000 + 0.043 + 0.007 = 0.575
df = 5
```

(i) Analysis of category of constructs by position of respondent

As displayed in table 9.94, the contingency table test of constructs by position of respondent produced a chi-square value of 3.01 which is much lesser than the chi-square value in the table (11.07 as shown in appendix F). We therefore also confirm that there is no difference in the proportion of constructs between directors and estimators.

Table 9.94 : Contingency table test of constructs by position of respondent

RESPONDENT CATEGORY	CATEGORY OF CONSTRUCTS					
	CONTRACT RELATED	INFORMATION RELATED	PROTECTION RELATED	PERSONNEL RELATED	WORK CONTENT RELATED	WORK NATURE RELATED
Estimators	12	37	14	34	19	30
Directors	2	19	7	17	12	18

MINITAB OUTPUT

```
Expected counts are printed below observed counts

            C1      C2      C3      C4      C5      C6    Total

   1        12      37      14      34      19      30      146
          9.25   37.00   13.87   33.69   20.48   31.71

   2         2      19       7      17      12      18       75
          4.75   19.00    7.13   17.31   10.52   16.29

Total       14      56      21      51      31      48      221

ChiSq =  0.818 + 0.000 + 0.001 + 0.003 + 0.107 + 0.092 +
         1.593 + 0.000 + 0.002 + 0.005 + 0.208 + 0.180 = 3.010
df = 5
```

Thus, the above statistical tests shows that risk perception of contractors is not influenced by the size of firm, specialism of firm and the position of the respondent.

9.7.2.3 Principal Component analysis (PCA)

This analysis aims to identify major or key dimensions which can be used to describe the risk perception of contractors in competitive bidding. In this research, the Flexigrid program version 4.0 as developed by Finn Tschudi (7) of the University of Oslo was adopted for analysing the fully rated grid. This program runs on a micro-computer and is written in the BASIC language. It provides a comprehensive and flexible method for analysing both the principal component analysis and cluster analysis. A friendly user interface has been developed to facilitate the input of data and analysis. Information obtained from the fully rated grid of the twenty-two contractors were coded and keyed into the program interactively. For the purpose of demonstrating the output of the program, the following example is provided displaying the results of one contractor.

In the principal component analysis, the main computer output as shown in tables 9.95 to 9.100 are briefly listed as follows:-

i) Table of minimum, mean, maximum and standard deviation score of each construct (table 9.95).

ii) A correlation table displaying relationships between the constructs (table 9.96).

iii) Table of principal components and factor scores (table 9.97).

iv) Table of varimax rotated components (table 9.98).

v) Graphical representations of elements and constructs to major dimensions (table 9.99 and figure 9.36)

As shown in table 9.95, the construct statistics are listed displaying the minimum, mean, maximum, standard deviation and the total percentage of variation of the assigned scores of each construct (in each row). The sum of squares of deviation from the mean is also calculated for each construct and the grand total of the variation of all the constructs (V) is aggregated. The percentage contributed by each construct to V is then computed and listed in the last column of table 9.95.

Table 9.95 : Table of construct statistics (PCA)

This table provides you with the minimum, mean, maximum and standard deviation of each variable
##

POLE	/CONTRAST	VBL.	MIN.	MEAN	MAX.	STD.DEV.	% OF TOTAL VAR.
good documentation	/poor documentation	1	1	3.50	7	2.22	12.97
vacant bldg	/occupied bldg	2	1	3.17	6	1.57	6.52
low intensity	/high intensity	3	1	2.50	6	1.71	7.69
low vandalism	/high vandalism	4	1	3.00	6	1.83	8.79
good quality design info	/poor quality design info	5	1	3.50	7	2.22	12.97
low % of specialist work	/high % of specialist work	6	2	3.67	6	1.37	4.98
easy cost estimate	/difficult cost estimate	7	1	3.50	7	1.93	10.33
good client relationship	/poor client relationship	8	2	3.00	5	1.15	3.52
good consultant relation	/poor consultant relation	9	3	4.50	7	1.38	5.05
low workload	/high workload	10	2	3.83	7	1.67	7.40
low risk	/high risk	11	1	3.50	6	1.89	9.45
low complexity	/high complexity	12	1	3.50	7	1.98	10.33
		Total mean		3.43		Mean var.	3.16

Table 9.96 : Correlation matrix of constructs (PCA)

Correlation table, showing the relationships between all the variables
##

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	0.12	1.00										
3	0.24	0.90	1.00									
4	0.08	0.06	0.32	1.00								
5	0.97	0.31	0.46	0.25	1.00							
6	0.93	0.41	0.57	0.20	0.98	1.00						
7	0.89	0.40	0.62	0.32	0.97	0.98	1.00					
8	0.52	-0.55	-0.34	0.55	0.46	0.32	0.36	1.00				
9	0.84	-0.11	0.04	-0.20	0.73	0.70	0.70	0.42	1.00			
10	0.88	0.52	0.67	0.27	0.96	0.99	0.98	0.26	0.61	1.00		
11	0.97	0.20	0.39	0.14	0.97	0.96	0.96	0.46	0.86	0.92	1.00	
12	0.89	0.40	0.62	0.32	0.97	0.98	1.00	0.36	0.70	0.98	0.96	1.00

Intensity (root mean square) +0.667 Mean absolute value +0.590

(Note: Constructs numbered according to table 9.95)

Table 9.97 : Table of principal components and factor scores (PCA)

Table of principal components
##############################

POLE	/CONTRAST	VBL.	1	2	3	DIST.	VAR-R	%ACC.
good documentation	/poor documentation	1	0.936	-0.274	-0.161	0.988	1.000	97.638
vacant bldg	/occupied bldg	2	0.365	0.907	-0.028	0.978	1.000	95.594
low intensity	/high intensity	3	0.550	0.800	0.170	0.985	1.000	97.091
low vandalism	/high vandalism	4	0.265	-0.004	0.960	0.996	1.000	99.289
good quality design info	/poor quality design info	5	0.989	-0.074	-0.005	0.992	1.000	98.373
low % of specialist work	/high % of specialist work	6	0.990	0.059	-0.058	0.993	1.000	98.631
easy cost estimate	/difficult cost estimate	7	0.994	0.060	0.056	0.997	1.000	99.385
good client relationship	/poor client relationship	8	0.396	-0.780	0.468	0.993	1.000	98.515
good consultant relation	/poor consultant relation	9	0.739	-0.426	-0.436	0.958	1.000	91.838
low workload	/high workload	10	0.979	0.177	0.022	0.995	1.000	99.008
low risk	/high risk	11	0.976	-0.171	-0.124	0.999	1.000	99.757
low complexity	/high complexity	12	0.994	0.060	0.056	0.997	1.000	99.385
%VARIANCE			66.066	20.036	11.772	97.875		

Factor scores
##############

	VBL.	1	2	3	DIST-N	*	DIST.	VAR-R	%ACC.
A	1	1.677	1.294	0.694	2.228	*	1.500	2.250	99.983
B	2	0.967	-1.367	-1.374	2.166	*	1.102	1.218	99.682
C	3	-0.289	-1.322	1.766	2.225	*	0.879	0.774	99.903
D	4	-1.198	0.660	-0.190	1.381	*	1.020	1.061	97.963
E	5	-0.762	0.405	-0.257	0.900	*	0.651	0.458	92.530
F	6	-0.395	0.331	-0.639	0.820	*	0.416	0.239	72.166

Variance of transformed data= 1   Variance of derived data= .9787523
Correlation transformed, derived .9893191

Table 9.98 : Table of varimax rotated components (PCA)

Table of VARIMAX rotated components
####################################

POLE	/CONTRAST	VBL.	1	2	3	DIST.
good documentation	/poor documentation	1	0.985	-0.062	0.039	0.988
vacant bldg	/occupied bldg	2	0.161	0.964	-0.033	0.978
low intensity	/high intensity	3	0.321	0.909	0.205	0.985
low vandalism	/high vandalism	4	0.063	0.092	0.990	0.996
good quality design info	/poor quality design info	5	0.963	0.150	0.185	0.992
low % of specialist work	/high % of specialist work	6	0.945	0.278	0.123	0.993
easy cost estimate	/difficult cost estimate	7	0.926	0.284	0.235	0.997
good client relationship	/poor client relationship	8	0.451	-0.653	0.595	0.993
good consultant relation	/poor consultant relation	9	0.885	-0.265	-0.254	0.958
low workload	/high workload	10	0.894	0.393	0.189	0.995
low risk	/high risk	11	0.995	0.048	0.075	0.999
low complexity	/high complexity	12	0.926	0.284	0.235	0.997
%VARIANCE			61.807	22.354	13.715	97.875

Table 9.99 : Graphical representation of constructs and elements on key dimensions (PCA)

```
F L E X I G R I D v4.0 Feb. 1987. File: cont15 Time: 11:43:40
GRID TITLE: cont15
TARGET ##############################################################

ANALYSIS based on rotated  results


Definition of ELEMENTS: TYPICAL #
                        IDEAL   +
                        WORST   £
---------------------------------------------------------------------------------------------------------------------------------------
                                                        Position of ELEMENTS
                                         NEGATIVE                                  POSITIVE
                        1                    2                    3                   4                    5
NEGATIVE POLE                                                     .                                          POSITIVE POLE
                                                                  .
.......................................................................................................................................
COMPONENT 1                                                       .                        '                 COMPONENT 1
                                                                  .                        '
high risk                                                         ########                                   low risk
poor documentation                                                ++++++++++++++++++++++++++++++             good documentation
poor quality design info              ££££££££££££££££££££££££££££                                           good quality design info
high % of specialist work                                         .                        '                 low % of specialist work
                                                                  .                        '
.......................................................................................................................................
COMPONENT 2                                                       .        '                                 COMPONENT 2
                                                                  .        '
vacant bldg                         ##############################                                           occupied bldg
low intensity                                                     ++++++++                                   high intensity
poor client relationship                                          £££££££££££££££££££££££££££££££££££££££    good client relationship
                                                                  .        '
.......................................................................................................................................
COMPONENT 3                                                       .    '                                     COMPONENT 3
                                                                  .    '
high vandalism          ##########################################                                           low vandalism
poor client relationship                                          ++++++++++                                 good client relationship
                                             £££££££££££££££££££££
                                                                  .    '
.......................................................................................................................................

                                                                  0       20       40       60       80       100
                                                                      ' MARKS IMPORTANCE OF COMPONENT
---------------------------------------------------------------------------------------------------------------------------------------
```

Figure 9.36 : Plot of elements and constructs on key dimensions (PCA)

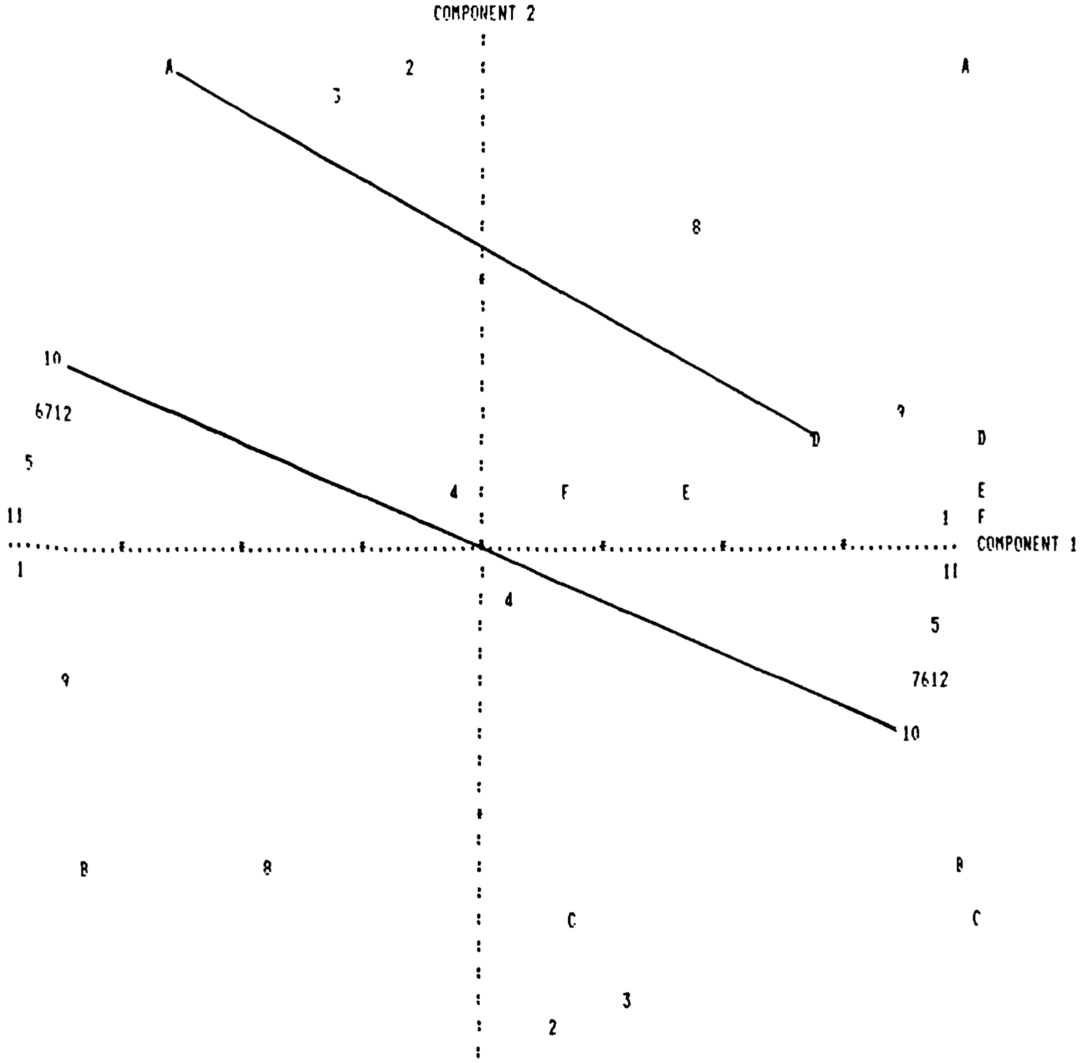
```
F L E X I G R I D v4.0 Feb. 1987. File: cont15 Time: 11:43:41
GRID TITLE: cont15
PLOT ##########################################################

ANALYSIS based on rotated results

Axis 1 has been reflected
ELEMENT 4   picked as an IDEAL
```

10 high workload
7 difficult cost estimate
12 high complexity
6 high % of specialist work
5 poor quality design info
11 high risk

2 occupied bldg
3 high intensity
4 high vandalism

8 good client relationship

9 good consultant relation
1 good documentation



1 poor documentation
9 poor consultant relation

8 poor client relationship

4 low vandalism
3 low intensity
2 vacant bldg

11 low risk
5 good quality design info
6 low % of specialist work
12 low complexity
7 easy cost estimate
10 low workload

The graphical output as shown in figure 9.36 describes the mathematical structure of the grid. Both the elements and constructs are located in relation to the first two components (as indicated by the X and Y axes in figure 9.36). Since the constructs are bi-polar, the two ends of each pole occur on the opposite sides of the origin. Constructs with extreme variation (extreme ratings) are located further from the origin and are normally considered to be the key constructs of the individual. Further information may be obtained by comparing contrasting pairs of elements along specific dimensions (those dimensions parallel to the elements). For example, figure 9.36 shows that the difference between the ideal (element 4) and worst (element 1) bidding situation for this contractor is seen along the low workload/high workload dimension (as indicated by the parallel lines).

Thus, the above procedure was performed on each of the twenty-two contractors so as to identify the key dimensions of their risk perception in competitive bidding for refurbishment work. From table 9.95, it is possible to identify the most variable constructs of each contractor. A summary of the three most variable constructs for each contractor was compiled from the computer printouts of the principal component analysis as shown in table 9.100. This listing shows the three most variable constructs contributing to the total variation of all constructs. Theoretically, it is possible to assume that those constructs with greater contributions to the total variation are those which the contractors adopt to discriminate between high and low risk situations. As depicted in table 9.100, it is observed that different contractors employ different constructs when distinguishing high or low risk bidding situations. There is no distinct general pattern across the twenty-two contractors. However, some constructs such as cost estimate, documentation and client relationship were frequently adopted by a number of contractors.

In order to identify the major dimensions required to describe the inter-relationships of the grid data, it is necessary to examine the percentage of variance explained by each of these dimensions. The percentages of variance of each key dimension of all the contractors were tabulated in table 9.101. The last column is an aggregation of all the variances of the key dimensions. The total variance determines the amount of variation of the grid data that is explained by the respective key dimensions of various contractors.

Table 9.100 : Most variable constructs for individual contractors (PCA)

CONTRACTOR CODE	MOST VARIABLE CONSTRUCTS		
20	Cost estimate	Workload	Client relation
5	Client credit	Documentation	Risk
9	Workload	Documentation	Liquated damages
29	Contract form	Public protection	Collateral warranty
613	Noise/dust protection	Risk	Cost estimate
27	Security	Intensity of work	Risk
16	Familiar client	Vacant building	Complicated job
24	Construction programme	Risk	Familiar work
30	Client relation	Vacant building	Contract form
14	Proportion of new work	Access	Work phase
83	Familiar client	Workload	Risk
190	Vacant building	Risk	Protection of expensive items/listed buildings
13	Risk	Structural work	Client relation
349	Complex	Risk	Access
33	Intensity of work	Vacant building	Liquidated damages
15	Documentation	Design information	Cost estimate
7	Client credit	Public protection	Access
31	Access	Cost estimate	Client relation
371	Percentage of retention	Access	Buildability
18	Vandalism	Access	Cost estimate
383	Number of bidders	Job size	Intensity of work
293	Vacant domestic building	Cost estimate	Internal/external refurbishment

The extraction of key dimensions from all the contractors shows that between 84% to 98% of the total variance of all constructs is attributable to 2 or 3 dimensions. Thus, it could be inferred that the risk perception of the contractors may be adequately represented by these major dimensions. Based on the percentage of variance contributed by each construct to each dimension, the most significant (highly associated) constructs for various major dimensions are listed in table 9.102. An attempt was made to examine the content of these highly associated constructs, there appeared to be a random spread of various categories of constructs in these dimensions. However, for some contractors it is possible to identify specific constructs which are influencing their risk perception. For example, contractor 9 (as shown in table 9.102) has the client relationship construct occurring in all his key dimensions. This implies that the client relationship is an important aspect of consideration in discriminating between a high or low risk bidding situation.

Table 9.101 : Cumulative percentage of total variation explained by different key dimensions (PCA)

CONTRACTOR CODE	KEY DIMENSIONS			TOTAL VARIANCE
	1	2	3	
20	54.34	22.81	11.93	89.08
5	51.55	22.83	14.13	88.51
9	54.85	21.00	12.23	88.08
29	58.85	23.00	13.06	94.91
613	73.08	12.16	-	85.24
27	77.54	10.33	7.15	95.02
16	54.24	27.29	10.63	92.16
24	48.18	25.45	12.44	86.07
30	44.53	23.65	15.86	84.04
14	37.81	30.70	17.80	86.31
83	64.07	19.99	10.63	94.69
190	49.39	31.46	16.38	97.23
13	63.20	23.55	8.47	95.22
349	51.29	24.17	13.69	89.15
33	58.55	30.83	-	89.38
15	66.07	20.04	11.77	97.88
7	52.88	27.32	12.31	92.51
31	52.50	29.93	15.28	97.71
371	45.57	32.58	13.70	91.85
18	45.47	29.99	18.30	93.76
383	37.32	29.09	19.98	86.39
293	45.53	27.09	13.73	86.35

Although no common dimension could be identified from the twenty-two contractors, the key dimensions of each contractor do correspond closely to the groups of constructs emerging from the cluster analysis (which is described later).

Table 9.102 : Constructs related to key dimensions of individual contractors (PCA)

CONTRACTOR CODE	MAJOR DIMENSIONS		
	DIMENSION 1	DIMENSION 2	DIMENSION 3
20	Noise/dust protection Quality requirement Intensity of work Complexity	Work load Cost estimate Consultant relation Risk	Access Structural work Public protection Intensity of work
16	Vacant building Documentation Simple job Access	Familiar client Security Consultant relation Simple job	Work load Risk Cost estimate Access
5	Complexity Protect existing building Documentation Access	Risk Cost estimate Client relation Job size	Consultant relation Access Client credit Protect existing building
9	Intensity of work Liquidated damages Work load Client relation	Client relation Cost estimate Work load Client relation	Complexity Access Consultant relation Client relation
29	Collateral warranty Contract form Cost estimate Protect existing building	Client relation Client credit Risk Contract form	Complexity Consultant relation Public protection Client relation
613	Intensity of work Documentation Risk Cost estimate	Protect existing building Noise/dust protection Client relation Cost estimate	
27	Contract form Risk Intensity of work Work phase	Protect existing building Access Security Work phase	Protect new work Complexity Noise/dust protection Restriction of work hours
24	Client relation Vacant building Competition Noise/dust protection	Contract period Risk Familiar work Competition	Complexity Risk Familiar work Noise/dust protection
30	Complexity Vacant building Cost estimate Risk	Contract form Client relation Consultant relation Client credit	Liquidated damages Noise/dust protection Access Cost estimate
14	Tender information Proportion of new work Cost estimate Fussy client	Risk Access Complexity fussy client	Work phase Fussy client Cost estimate Complexity

Table 9.102 : Constructs related to key dimensions of individual contractors (cont'd)

CONTRACTOR CODE	MAJOR DIMENSIONS DIMENSION 1	DIMENSION 2	DIMENSION 3
83	Risk Consultant relation Work load Client relation	Access Complexity Consultant relation Client relation	Specification of hours Client credit Cost estimate Documentation
190	Complexity Cost estimate Structural demolition Client relation	Consultant relation Vacant building Protection of building listed building Client relation	Risk Access Protection of listed building Client relation
13	Cost estimate Complexity Structural work Access	Vacant building Client relation Client credit Consultant competence	Work load Consultant competence Client credit Number of bidders
349	Risk Client relation Complexity Access	Client relation Complexity Access Client relation	Ground work Consultant relation Risk Client credit
33	Risk Commercial client Intensity of work liquidated damages	Client relation Consultant relation Vacant building Cost estimate	
15	Risk Documentation Design information Proportion of specialist work	Vacant building Intensity of work Client relation Work load	Vandalism Client relation Consultant relation Cost estimate / complexity
7	Protect existing building Temporary work Timely start of project Access	Public protection Documentation Risk Consultant relation	Complexity Cost estimate Consultant relation Client credit
31	Complexity Risk Access Cost estimate	Consultant relation Client credit Intensity of work Risk	Work load Client relation Documentation Client credit
371	Complexity of own work Risk Cost estimate Buildability	Retention percentage Complexity of sub work Client relation Consultant relation	Client credit Noise/dust protection Work load Consultant relation
18	Cost estimate Access Risk Work load	Vandalism Vacant domestic building Complexity Work load	Consultant relation Client relation Complexity Vandalism
383	Access Cost estimate Temporary work Consultant competence	Client Credit Number of bidders Client relation Intensity of work	Job size Risk Intensity of work Consultant competence
293	Vacant domestic building Risk Access Cost estimate	Consultant relation Client relation Internal/External refurb Competition	Work load Competition Internal/External refurb Cost estimate

An investigation was also carried out to determine the relationship between the pre-determined risk construct (which refers to the overall risk assessment rating of the respective bidding situation) and other elicited constructs. The main purpose is to identify whether specific constructs are often present in high risk bidding situations. Table 9.103 provides a list of constructs which are frequently and closely associated with the risk construct of the selected sample of contractors. As shown in table 9.103, three constructs were found to be highly correlated to the risk construct. They are listed in descending order of frequency of occurrences as follows:-

a) Degree of difficulty in pricing cost estimate.

b) Restriction of access.

c) Degree of complexity of work.

Table 9.103 : Frequency analysis of constructs associated with risk construct

SNO	CONSTRUCTS ASSOCIATED WITH RISK CONSTRUCT	FREQUENCY
1	Cost estimate	11
2	Access	8
3	Complexity	6
4	Work load	4
5	Intensity of work	4
6	Documentation	4
7	Job size	2
8	Contract form	2
9	Noise dust protection	2
10	Consultant relation	2
11	Collateral warranty	1
12	Public protection	1
13	Restriction of work hours	1
14	Contract period	1
15	Client relation	1
16	Structural work	1
17	Number of bidders	1
18	Vacant building	1
19	Ground work	1
20	Commercial client	1
21	Proportion of specialist work	1
22	Design information	1
23	Complexity of own work	1
24	Buidability	1
25	Vacant domestic building	1

The preparation of cost estimate involves much financial risks such as cost overrun or abortive tendering costs. Its accuracy is influenced by numerous factors both within the control and beyond the control of the estimator. The degree of difficulty in pricing a cost estimate depends on the tender documentation, nature of work and the experience of the estimator. Information is the key determinant influencing the extent of risk faced by the contractor when tendering.

As illustrated in table 9.103, access restrictions and the degree of complexity of work have much influence on the risk assessment of the contractors during tendering. As described in chapter two, one of the unique and problematic characteristic of refurbishment is accessibility of work. Very often, contractors are faced with much difficulty in assessing the impact on restricted access on the productivity of labour, costs of material handling and storage, co-ordination and control of work, costs of providing various protective measures. The relationship between risk and complexity of job is mainly attributed to the capacity and capability of the contractors. Complex jobs are often referred to those that demand a large input of management effort in planning and co-ordinating the construction process.

Table 9.104 provides a description of various construct poles which are related to the worst bidding situation of individual contractors. There are no distinct constructs which are commonly adopted to describe the worst bidding situation. Each individual contractor has an unique set of constructs associated to his own worst bidding situation. This is probably due to the characteristic strengths and weaknesses of individual contractors. The worst bidding situation is also influenced and conditioned by the past experiences of individual contractors. Most contractors perceive different characteristics of a bidding situation as high or low risk to his company. The evidence from the data clearly shows that different contractors perceived their least preferred bidding situation differently.

Table 9.104 : Construct poles related to the worst bidding situation of individual contractors

CONTRACTOR CODE	CONSTRUCTS
20	Low work load Easy cost estimate Poor consultant relation Low risk
16	Occupied building Poor documentation High Complexity Difficult access
5	High risk Difficult cost estimate Poor client relation Small job size
9	HIgh risk Difficult cost estimate High work load Poor client relation
29	No collateral warranty Standard contract form Easy cost estimate No protection of existing building
613	No protection of existing building Poor client relation Difficult cost estimate
27	No protection of existing building Easy access Low security Single phase
24	Reasonable contract period Low risk Unfamiliar work Known competition
14	Low risk Easy access Low complexity
30	High complexity Vacant building Difficult cost estimate High risk
83	Easy access Low complexity

Table 9.104 : Construct poles related to the worst bidding situation of individual contractors (cont'd)

CONTRACTOR CODE	CONSTRUCTS
190	Low complexity Easy cost estimate No structural demolition Good client relationship
13	Vacant building Poor client relation Low consultant competence High client credit
349	Low complexity High client credit
33	Low risk Non commercial client Low Liquidated damages Low intensity of work
15	High risk Poor documentation Poor design information High proportion of specialist work
7	No public protection Poor documentation High risk Poor consultant relation
31	High complexity High risk Difficult access Easy cost estimate
371	High retention High complexity of sub-contract work High complexity
18	Low vandalism Vacant domestic building High complexity
383	Easy access Difficult cost estimate No temporary work good consultant relation
293	Vacant domestic building Low risk Easy access Easy cost estimate

During the grid interview, each contractor was also requested to describe the characteristics of an ideal bidding situation to his firm. The main purpose is to explore whether all contractors share the same opinion with regard to their ideal bidding situation. The list of characteristics which were employed were listed in table 9.105. A frequency count analysis was performed to determine which characteristics are most frequently mentioned by the contractor. From table 9.105, an ideal bidding situation is characterised by the following features:-

a) High intensity of work.

b) Good client relationship.

c) Prime location.

Table 9.105 : Characteristics of ideal bidding situations as described by contractors

SNO	IDEAL BIDDING SITUATION CHARACTERISTICS	FREQUENCY
1	High intensity of work	13
2	Good client relationship	10
3	Prime location (Publicity)	7
4	Office building	6
5	Complex job	5
6	Good consultant relationship	4
7	Low risk	3
8	Client with repeat work	2
9	Near office location	2
10	Residential building	2
11	Occupied building	2
12	Lots of structural work	2
13	High risk	2
14	Good quality building	2
15	Good competition mix	2
16	Difficult access	2
17	Good documentation	2
18	Involves steelwork alteration	1
19	Reasonable mix trades	1
20	Well established client	1
21	Good client credit	1
22	Reasonable contract period	1
23	Classical refurbishment work	1
24	Few bidders	1
25	High profit	1
26	Hospital building	1
27	Prestigious job	1
28	Fitting out job	1
29	Reasonably designed	1

Thus, the Principal Component analysis shows that the key dimensions of risk perception vary among individual contractors. This result confirms that individual contractor perceives risk differently in competitive tendering for refurbishment work.

9.7.2.4 Cluster analysis of grid

The cluster analysis of the constructs provides another method of analysing the relationships of constructs for individual constructs. This attempts to group constructs and elements of contractors in clusters so as to identify the relationships between the elements and constructs. The main computer output for the cluster analysis are listed as follows:-

i) Matching scores for construct matrix (table 9.106).
ii) Matching scores for element matrix (table 9.107).
iii) Element tree (figure 9.37) .
iv) Construct tree (figure 9.38).

From the cluster analysis of individual contractor, the main clusters of constructs for each individual contractor are shown in table 9.108. From table 9.108, it is observed that the clustering of constructs is unique to each individual contractor. A visual inspection of the constructs indicates that most contractors adopt two or three groups of constructs to discriminate between high and low risk bidding situations.

Table 9.106 : Matching scores of construct matrix

Matching scores for CONSTRUCTS matrix is focused
Upper right part gives matching scores - SIMILARITIES
Lower left part gives matching scores when the column of CONSTRUCTS is reflected

	8	4	3	2	6	10	12	7	5	1	11	9	
8		67	39	28	56	50	50	50	50	50	50	39	
4	0		61	39	44	39	39	39	39	39	39	28	
3	6	-17		78	61	56	56	56	44	44	56	22	
2	28	6	-22		61	56	44	44	33	33	44	33	
6	33	11	-6	17		94	83	83	72	72	83	61	
10	28	6	-11	11	6		89	89	78	67	78	56	
12	17	-6	-22	0	-6	-11		100	89	78	89	44	
7	17	-6	-22	0	-6	-11	-22		89	78	89	44	
5	6	-6	-22	0	-17	-22	-33	-33		89	89	44	
1	6	6	-11	0	-17	-22	-33	-33	-44		89	56	
11	17	6	-11	11	-6	-11	-22	-22	-33	-33		56	
9	39	39	33	44	28	22	11	11	0	0	11		
CENTRALITY and TOTAL CONNECTEDNESS	48	43	52	45	70	68	69	69	65	63	69	44	60

Note : Constructs - same as sequence as in GRID above.

8 good client relationship/poor client relationship.
4 low vandalism/high vandalism.
3 low intensity/high intensity.
2 vacant building/occupied building.
6 low % of specialist work/high % of specialist work.
10 low workload/high workload.
12 low complexity/high complexity.
7 easy cost estimate/difficult cost estimate.
5 good quality design info/poor quality design info.
1 good documentation/poor documentation.
11 low risk/high risk.
9 good consultant relation/poor consultant relation.

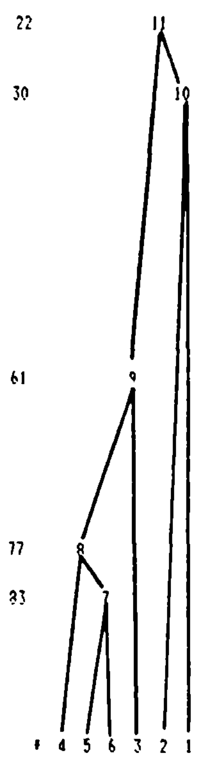
Table 9.107 : Matching scores of element matrix

Matching scores for ELEMENTS matrix is focused

	4	5	6	3	2	1
4		78	61	33	-11	-36
5	78		83	56	11	-19
6	61	83		61	22	-3
3	33	56	61		22	-8
2	-11	11	22	22		31
1	-36	-19	-3	-8	31	
CENTRALITY and TOTAL CONNECTEDNESS						
25	42	45	33	15	-7	26

Figure 9.37 : Element tree

FOCUSED GRID ##



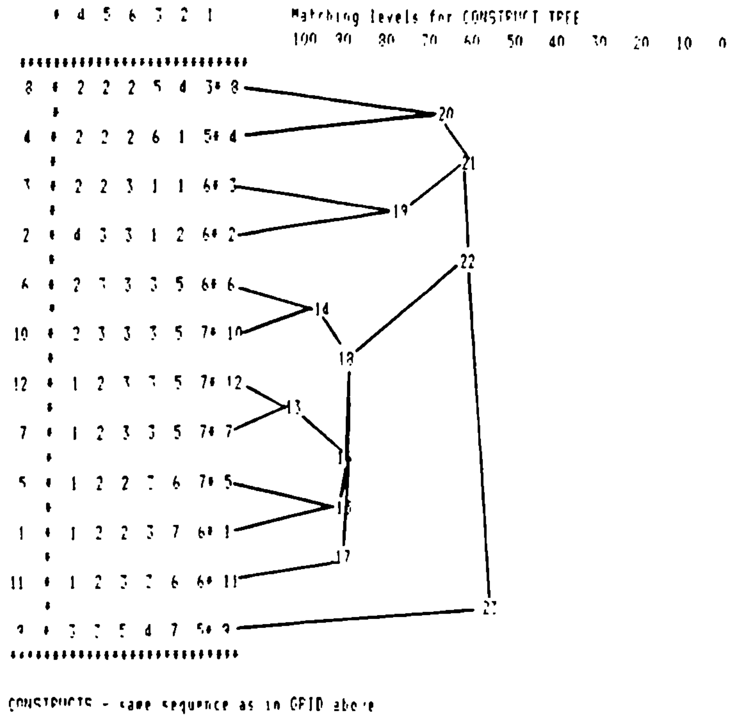
To draw the ELEMENT TREE

		matching	mean similarity between clusters	inner simi	middle simi	difference	z-score
join 5 and 6	above into cluster 7	83.33 %	83	83	33	50	1.449
join 4 and 7	above into cluster 8	77.78 %	69	74	13	61	2.480
join 8 and 3	above into cluster 9	61.11 %	50	62	-3	65	2.834
join 2 and 1	above into cluster 10	30.56 %	31	31	-3	33	0.966
join 9 and 10	above into cluster 11	22.22 %	-3	25	0	0	0.000

Goodness of fit correlation (cophenetic correlation) 0.903   mean z-score 1.932

(Note: Elements 1 to 5 refer to different bidding situations)

Figure 9.38 : Construct tree



(Note: Sequence of constructs as in table 9.106)

Thus, the results of the cluster analysis confirm that most contractors employ two to three key dimensions in discriminating between high and low risk bidding situations. It also shows that individual contractors have unique set of key dimensions which describe their risk perception in competitive bidding.

Table 9.108 : Cluster analysis of constructs of individual contractors

CONTRACTOR CODE	GROUPING OF CONSTRUCTS		
	CLUSTER 1	CLUSTER 2	CLUSTER 3
20	Intensity of work Risk Noise/dust protection Quality requirement	Public protection Access Cost estimate	Structural work Complexity Client relationship Consultant relationship Workload
16	Documentation Complexity Cost estimate Consultant relation Security Vacant building	Risk Work load Access Familiarity of client	
5	Client credit Documentation Client relationship	Cost estimate Risk Job size Consultant relation	Complexity Protect existing bldg Access
9	Vacant building Access Complexity	Documentation Client relation Consultant relation Intensity of work Liquidated damages	Cost estimate Risk
29	Complexity Client relation Consultant relation Client credit	Cost estimate Risk Contract form Collateral warranty Public protection Protect existing bldg	
613	Intensity of work Documentation Cost estimate Risk	Protect existing bldg Client relationship	
27	Work phase Cost estimate Contract form Complexity	Restriction of work hours Noise dust protection Intensity of work Risk	Security Access Protect exist bldg
24	Competition Client relation Vacant building	Contract period Risk	

Table 9.108 : Cluster analysis of constructs of individual contractors (cont'd)

CONTRACTOR CODE	GROUPING OF CONSTRUCTS		
	CLUSTER 1	CLUSTER 2	CLUSTER 3
14	Cost estimate Complexity Risk Access	Prop. of new work Tender information Fussy client	
30	Liquidated damages Protection of listed bldg Noise/dust protection Consultant relationship Client credit	Complexity Cost estimate Access Risk Client relationship Contract form	Temporary work Occupied building
83	Work load Consultant relation Risk Client relationship Documentation	Spec of work hours Client credit	complexity Access
190	Structural demolition Complexity Cost estimate	Protect expensive items Consultant relationship Client relationship Vacant building	Risk Access
13	Structural work Complexity Cost estimate Number of bidders Access Risk Vacant building	Work load Consultant competence Client relation Client credit	
349	Client credit Client relationship Consultant relationship Ground work	Access Complexity Risk	
33	Restrict work hours Intensity of work Liquidated damages Access	Commercial client Risk Noise/dust protection	Cost estimate Client relationship Consultant relationship
15	Client relationship Vandalism Intensity of work Vacant building	Prop. of specialist work Work load Complexity Cost estimate Design information Documentation Risk	

Table 9.108 : Cluster analysis of constructs of individual contractors (cont'd)

CONTRACTOR CODE	GROUPING OF CONSTRUCTS		
	CLUSTER 1	CLUSTER 2	CLUSTER 3
7	Risk Documentation Consultant relationship	Contract period Timely start Protect existing bldg Client relationship Client credit Temporary work Cost estimate	
31	Intensity of work Risk Complexity Documentation Cost estimate	Client relationship Client credit Consultant relationship Workload	
371	Client credit Work load Complexity of sub work Client relationship Consultant relationship	Complexity of own work Risk Buildability Noise/dust protection Cost estimate Prop of own labour Access	
18	Access Cost estimate Risk Work load	Complexity Consultant relationship Client relationship Vacant domestic bldg	
383	Temporary work Cost estimate Access	Number of bidders Client credit Client relationship Consultant competence Complexity	Risk Job size Intensity of work
293	Risk Cost estimate Vacant domestic building Access	Consultant relationship Client relationship Work load Number of bidders Internal External refurb	

CHAPTER TEN

CONCLUSIONS AND FUTURE WORK

CHAPTER TEN

SUMMARY OF FINDINGS AND CONCLUSIONS

10.1 Introduction

This chapter summarises the main findings of this study. It restates the main objectives of the research and discusses the strengths and weaknesses of the adopted research methodology in fulfilling the objectives. The results of the findings are organised according to the modules of the decision support and risk management system. Besides this, recommendations are also made to direct future research efforts into other potential areas of risk management in the construction industry.

10.2 Main findings of research

The main findings of the research are summarised as follows:-

A) Module 1 - Databases of tender bid records and repertory grid data

The decision support and risk management system has two main databases namely: (i) tender bid records, and (ii) repertory grid data. The tender bid database consists of 2261 cases of refurbishment contracts (lump sum contracts) and was set up in the mainframe computer (DEC VAX 8700) at Heriot-Watt University. The repertory grid data consists of fully rated grid obtained through the interview of twenty-two refurbishment contractors (directors and estimators). It contains information on the risk perception constructs of contractors (directors and estimators) in competitive tendering. This information is stored in a micro-computer which uses a specially developed program called Flexigrid for analysis.

B) Module 2 - General information of bidding characteristics

i) Descriptive statistics of tender bids (Population analysis)

1) The distribution of the number of bidders per contract is positively skewed with more contracts having four to five bidders (49.3% of all contracts). The mean number of bidders for the refurbishment work studied is 4.80 and has a standard deviation of 1.42. A comparison of mean number of bidders between new-build and refurbishment shows that refurbishment work had relatively fewer bidders in competition per contract. This implies that refurbishment contracts are generally less competitive as compared to new-build work.

2) A large proportion of refurbishment contracts (52.6%) was within the £100,000 to £500,000 value range. While only 2.2% of all refurbishment contracts in the sample (2261 contracts) had contract values exceeding £3m.

3) The refurbishment of office (28.3%) and residential (37.3%) buildings constituted a large proportion of all refurbishment work in London (from 1984 to 1989). While the refurbishment of religious buildings accounted for only 1.2% of all contracts.

4) The histogram of tender bids arranged according to job location shows that most refurbishment contracts (73.6%) of the sample were concentrated in London and Greater London.

5) There was an equal distribution of jobs between the public (46.6%) and private (53.4%) sectors in the sample of refurbishment contracts.

6) The distribution of bid range of tender bids indicates that bid range varied considerably between 1.0% and 88.8% in refurbishment work. The mean bid range was 20.6% and thus indicates that the risk perception of contractors varied quite

differently when tendering for refurbishment contracts.

7) The distribution of bid RD is positively skewed and has a mean of 11.0%. It ranges from 0.4% to 62.2% and thus confirms that tender bids were widely spread in refurbishment work. This could be attributed to the inherently precarious nature of refurbishment work.

8) The distribution of bid spread is significantly positively skewed with a mean of 6.2% and standard deviation of 6.8%. The median bid spread is 4.1% which implies that 50 percent of all refurbishment contracts were secured by contractors with at least 4% of contract value being "left on the table". The comparison of jobs with bid spread greater than or equal to any given amount between new-build and refurbishment work displays similar trends. This suggests that the proportions of jobs with various bid spread were equal for both new-build and refurbishment work.

9) The skewness of tender bids in refurbishment work has a mean of 0.1 and standard deviation of 0.6. This clearly shows that refurbishment contracts are approximately symmetrically distributed and thus are less competitive in nature.

10) The kurtosis of bids varies considerably between -2.9 and 3.0. The mean kurtosis is -1.1 and has a standard deviation of 0.6. This result indicates that the peakedness of tender bids for each contract varies quite considerably.

ii) Descriptive statistics of tender bids (Sub-population analysis)

The descriptive statistics of tender bids under different job characteristics are provided in tables 9.5, 9.7, 9.9, 9.12, 9.14, and 9.16. The results of the one-way analysis of variance of various bidding characteristics by job characteristics are summarised in table 10.1.

Table 10.1 : One-way analysis of variance of bidding characteristics

BIDDING CHARACTERISTICS	ACCEPT OR REJECT HYPOTHESIS					
	YEAR OF TENDER	JOB TYPE	JOB SIZE	CLIENT TYPE	JOB LOCATION	NO. OF BIDDERS
Number of bidders	Reject	Reject	Reject	Reject	Reject	-
Bid range	Reject	Reject	Reject	Accept	Reject	Reject
Bid RD	Reject	Reject	Reject	Accept	Reject	Reject
Bid spread	Accept	Reject	Reject	Reject	Reject	Reject
Skewness	Reject	Accept	Accept	Accept	Accept	Accept
Kurtosis	Accept	Reject	Reject	Accept	Reject	Reject

Note: a) Reject hypothesis indicates that we have statistical evidence that the population means of the specified bidding characteristic are not equal for different categories of the job characteristics.

b) Accept hypothesis indicates that we have no statistical evidence that the specified bidding characteristic is affected by different categories of the specified job characteristic.

iii) Competitive pattern of tender bids

1) **Number of bidders and job size** - Contracts which are less than £250,000 tended to attract 3 to 4 bidders (about 60-70% of all contracts) and thus are generally less competitive in nature. However, as project size increases, the number of bidders in competition also increases. This pattern is more discernible in jobs of value between £250,000 and £1.75m. This range of contracts usually attracted 3 to 10 bidders in competition indicating more intense competition. On the other extreme, large contracts which were over £3m tended to have relatively fewer bidders (5 to 6) in competition.

2) **Number of bidders and job type** - The refurbishment of industrial, recreation and entertainment, and religious buildings had generally fewer bidders (usually less than 7 bidders) in competition as compared to education, scientific and information, office and administration, and residential buildings.

3) **Number of bidders and year of tender** - The analysis of number of bidders shows that in all years (1984 to 1989), most refurbishment contracts tended to attract between 3 and 6 bidders. However, there were relatively more jobs with 5 or more bidders in 1986 and 1989 indicating higher competition in those years.

4) **Bid spread and job size** - The bid spread varied considerably particularly for jobs below £750,000. It was found that a large proportion of small contracts (less than £500,000) had bid spread over 14%. This is mainly attributed to the mix of competition (contractors of different firm sizes and capabilities) for these small contracts. On the other hand, large jobs of over £2m had relatively lower bid spread (about 2% to 4%). This is mainly due to the comparability of bidders competing for such contracts.

5) **Bid spread and job type** - Most job types had a large proportion of contracts (60% to 70%) with bid spread between 0% and 6%. However, industrial buildings tended to have relatively more contracts with lower bid spread (less than 3%) while residential buildings had comparatively more contracts with bid spread over 14%.

6) **Bid spread and year of tender** - There is no discernible pattern observed in the distribution of jobs with various bid spread for different years of tender.

7) **Bid RD and job size** - It was found that there were more contracts in the lower job range (less than £500,00) with high bid RD (over 18%) as compared to those jobs over £2m. The bid RD of tender bids tends to decrease as job size increases.

8) **Bid RD and job type** - Industrial buildings had more contracts with lower bid RD (less than 3%) while a large proportion of residential buildings had bid RD over 18%. This suggests that the refurbishment of industrial buildings was less risky in nature than residential premises.

9) **Bid spread and year of tender** - There is no discernible difference in the distribution of jobs with various bid RD for different years of tender. In most years (1984 to 1989), a large proportion of contracts had bid RD between 3% and 9%.

iv) Correlation analysis of bidding variables

The correlation analysis of various bidding variables shows that both the dispersion of tender bids (bid range and bid RD) and level of competitiveness (bid spread) are influenced by job size and number of bidders. Generally, both bid dispersion and level of competitiveness tended to decrease as job size and number of bidders increased. The results of the analysis are summarised in table 10.2.

Table 10.2 : Correlation analysis of bidding variables

BIDDING VARIABLES (LOGARITHM)	CORRELATION COEFFICIENT	REMARKS
Bid range vs Job size	-0.26	Significant but weak linear correlation
Bid range vs No. of bidders	0.13	Significant but weak linear correlation
Bid RD vs Job size	-0.35	Significant but weak linear correlation
Bid RD vs No. of bidders	-0.12	Significant but weak linear correlation
Bid spread vs Job size	-0.23	Significant but weak linear correlation
Bid spread vs No. of bidders	-0.21	Significant but weak linear correlation

C) Module 3 - Contractor's analysis

A simple information search framework has been developed whereby tender bid information of past contracts of contractors may be retrieved in an understandable form to assist contractors to monitor their bidding performance and that of their competitors. The main measures adopted for evaluating and monitoring bidding performance include tender success rate, tender success value, win/lose margin distribution, and contractor's bid to mean bid ratio.

D) Module 4 - Competitors' analysis

Using the same approach as discussed above, this module provides a framework which enables a contractor to monitor the bidding performance of his competitors. Besides this, it also identifies the strengths and weaknesses of the competitors with respect to different bidding situations.

E) Module 5 - Bidding models

Two bidding models are developed by fitting past tender records of refurbishment contracts into either a Normal distribution or an Edgeworth distribution. The distribution of tender bids and the test of normality (using skewness and kurtosis test) indicates that the distribution of tender bids in refurbishment work (lump sum contracts) is approximately normal. Thus, it is reasonable to assume normality in the distribution of bids or to fit the bids into an Edgeworth distribution using the principles of the Central Limit Theorem.

From the fitted distributions (Normal or Edgeworth), it is possible to predict the distribution of the lowest bid of each contract using Order statistics. As such, it enables a contractor to predict the probability of success when submitting a bid in various bidding situations. The main parameters required for both models are as follows:-

i) Number of bidders against whom the contractor is competing.
ii) True skewness and true kurtosis of tender bids.
iii) Reciprocal of true coefficient of variation of tender bids.
iv) Cost estimate of proposed job.
v) The predicted bid mean of the proposed job.

Both bidding models have been tested on five refurbishment contractors with reasonable success. The predictions obtained from both models (Normal and Edgeworth distribution models) are very similar. However, it must be noted that these models have been tested on a relatively small sample of contractors and thus must be applied with caution in practice bearing in mind the assumptions made in the models.

F) Module 6 - Risk management system

i) Questionnaire survey of contractors

1) From the questionnaire survey of 47 refurbishment contractors, the most significant factors affecting the pricing decisions of contractors during tender adjudication are identified as follows:-

   a) Accuracy of contractor's cost estimate.
   b) Credit worthiness of client.
   c) Contractual liabilities.
   d) Type of job.
   e) Relationship with consultants.
   f) Relationship with clients.
   g) Workload commitment of contractor.
   h) Complexity of work.
   i) Size of job.
   j) Amendments to standard contract form.

2) A closer examination of the ratings which have been assigned to various tender adjudication factors shows that most contractors tended to place more emphasis on personnel relationships when adjudicating their tender. While factors relating to the general market and political conditions were of least importance when adjudicating a tender.

3) The frequency analysis of the rating responses of various tender adjudication factors reveals five distinct types of distributions of the rating as follows:-

a) Significantly negatively skewed factors.
b) Slightly negatively skewed factors.
c) Normally distributed factors.
d) Significantly positively skewed factors.
e) Uniformly / Bi-modally distributed factors.

4) The two-way analysis of variance test provides strong statistical evidence that the mean score rating varies both between tender adjudication factors and different sizes of firm (small, medium and large firms). The test also confirms that there is no discernible difference in the mean score between refurbishment specialists and general contractors. Statistical evidence has also shown that the mean score of rating does not vary between directors and estimators. Thus, the above results indicate that differences in judgement among contractors on the importance of various tender adjudication factors is influenced by the size of the firm.

5) The Kendall's Coefficient of Concordance test shows that all contractors were in agreement that the order of pricing difficulty (in terms of assessing the financial risks involved) for different job types are as follows:-

a) Health and Welfare (most difficult in pricing).
b) Religious.
c) Refreshment, Recreation and Entertainment.
d) Education, Scientific and Information.
e) Transport and Utility.
f) Administration and Office.
g) Residential.
h) Industrial (least difficult in pricing).

6) Most refurbishment contractors (78.8%) adopt group decision making strategy when adjudicating a tender. There is no discernible differentiating pattern observed between small, medium and large sized firms.

7) The main construction risks faced by contractors in refurbishment work are (i) accessibility of work (mean rating score = 5.2) and (ii) productivity of work force and plant (mean rating score = 5.0).

8) The most commonly adopted risk management strategy in competitive bidding is risk reduction strategy. Most refurbishment contractors attempt to reduce risk by obtaining information from various sources such as clients, consultants, sub-contractors, suppliers, independent organisations (for example, Builders' Conference), and their own records.

ii) Risk perception of contractors (Repertory Grid Interview)

1) From the frequency analysis of the personal constructs (both free response and pre-determined constructs) of the twenty-two refurbishment contractors (directors and estimators) interviewed, the most frequent constructs which were adopted by refurbishment contractors in discriminating between high or low risk bidding situations are as follows:-

a) Degree of difficulty in pricing cost estimate.
b) Client relationship.
c) Restricted access.
d) Degree of complexity of work.
e) Consultant relationship.
f) Workload of contractor.
g) Number of bidders.
h) Size of job.

i) Identity of bidders.

2) The Chi-square tests on the frequency of different job characteristics (client type, job type, job size and job location) indicate that high and low risk bidding situations are distributed in similar proportions in different job characteristic categories.

3) From the Content analysis of the elicited constructs, it is possible to group the risk perception constructs of refurbishment contractors into six main categories:-

a) Contract related constructs.
b) Information related constructs.
c) Protection related constructs.
d) Personnel related constructs.
e) Work content related constructs.
f) Work nature related constructs.

4) The Contingency table test reveals that the distribution of various categories of constructs are in the same proportion for different firm size, different firm specialism and different respondent type.

5) The most variable constructs as determined by the Principal Component analysis are different for all contractors. However, the more common variable constructs among the contractors are as follows:-

a) Degree of difficulty in pricing cost estimate.
b) Relationship with client.
c) Tender documentation.

6) The Principal Component analysis identifies that most contractors' risk perception constructs may be explained by two or three major dimensions. The key dimensions for each contractor are unique and different from other contractors. The analysis shows that between 84% to 98% of the total variance of all constructs for each individual contractor is attributable to two or three key dimensions. The highly correlated constructs of each dimension of individual contractors are also different among individual contractors.

7) The most frequent constructs that are related to the risk construct of all contractors are as follows:-

   a) Degree of difficulty in pricing cost estimate.
   b) Restriction of access.
   c) Degree of complexity of work.

8) The construct poles related to the worst bidding situation of individual contractors also vary considerably. This is mainly attributed to the respective strengths and weaknesses of individual contractors and their past experiences.

9) The common characteristics present in the various respective ideal bidding situations of contractors are as follows:-

   a) High intensity of work.
   b) Good client relationship.
   c) Prime location.

10) The Cluster analysis shows that the risk perception constructs of most contractors may be grouped into two or three clusters. These clusters of constructs differ between contractors but do correspond very closely to those highly correlated constructs obtained in the Principal Component analysis.

10.3 Conclusions and discussions

This study aims to provide a systematic and objective approach to risk management in competitive tendering for refurbishment work. It attempts to develop a framework whereby both quantitative (tender bid information) and qualitative (risk perception of bidders) information may be organised so as to provide strategic information to support the decision making processes of contractors in competitive bidding.

From the analysis of 2261 tender bid records (lump sum refurbishment contracts), a questionnaire survey of forty-seven refurbishment contractors, and personal interviews of twenty-two estimators/directors of construction firms, a decision support and risk management system is developed. This system consists of six main modules namely:- (i) Databases of tender bid records and repertory gird data, (ii) General information of bidding characteristics, (iii) Contractor's analysis, (iv) Competitors' analysis, (v) bidding models, and (iv) Risk management system.

The research adopts both quantitative and qualitative approaches to risk management in competitive tendering. Using a combination of both archival and opinion research methodologies, two main databases comprising tender bid records and information on the risk perception of contractors (directors and estimators) are set up in the decision support and risk management system. The main advantages of the archival research method is that it provides a flexible and versatile approach to collecting a relatively large sample of data and also provides the means for accessing and manipulating the data. As such, this approach has been adopted to collect and analyse the 2261 tender bid records which were obtained through the Builders' Conference in London. However, this method does suffer some limitations such as selective deficiencies, selective suicidal, selective retrieval, "filling in the gap", and biases from the researcher.

With regard to the collection of information on risk perception of contractors, the opinion research methodology is considered to be appropriate as the required information is highly subjective and sensitive. Two principal techniques, namely: (i) questionnaire survey, and (ii) Repertory Grid interview, were utilised to elicit information on the risk management strategies and risk perception of contractors. There are numerous benefits which accrue from the use of the opinion research methodology. It provides a simple, direct, inexpensive, effective and consistent means of obtaining qualitative information. However, this approach also suffers from certain deficiencies, particularly in the use of the questionnaire survey which is often criticised for failing to obtain an adequate response rate and response bias. In this study, attempts have been made to overcome such weaknesses through the use of various follow-up techniques.

Thus, despite the above limitations, this study has made a significant contribution to the management of risks in competitive bidding. It has provided a new dimension and approach which enables contractors to identify and manage risks more effectively. Common problems faced by contractors as a result of lack of information have been identified and the proposed decision support and risk management system has proved to be an effective risk management tool. The system enables contractors to obtain strategic information about their competitive environment and the bidding behaviour of their firms and their respective competitors. It also enhances the understanding of contractors with respect to risk management in competitive tendering and thus improves the quality of their decisions in competitive tendering.

Besides this, pertinent risk factors which affect the risk assessment of contractors under different tendering situations were also identified. This has increased the knowledge and understanding of contractors and has also provided useful guidelines for contractors to focus their efforts on managing these risks more effectively.

However, it must be noted that the results of this research are based upon 2261 tender bid records, a questionnaire survey of forty-seven contractors and personal interviews of twenty-two contractors. Although the sample is statistically representative of refurbishment contractors in the London area, it does not represent all refurbishment contractors in the

United Kingdom construction industry. Furthermore, due to constraints imposed by the availability of tender bid information, only significant bidding variables such as bid dispersion, level of competitiveness, and various job characteristics (year of tender, job type, job size, client type, job location and number of bidders) were considered in the analysis. This study has not specifically considered the impact of market forces such as political, social, technological and economic factors on the bidding characteristics of refurbishment contractors although the questionnaire survey and repertory grid interview do provide indications of how contractors perceive such factors in tendering.

Another factor to be considered is that the analysis of the tender bids is based upon past tender data under market conditions and the tendering policies of various firms at that time. As a result, such information could only be used as a guide for predicting the future behaviour of competitors (as bidding behaviour and policies of competitor will probably change). However, the decision support and risk management system does provide the flexibility for updating its databases so as to provide more updated information on the bidding characteristics of refurbishment work and the behaviour of contractors and competitors.

10.4 Recommendations for future work

As discussed above, this study has provided an integrated approach to risk management in competitive tendering for refurbishment work (lump sum contracts). It has demonstrated that both bidding and risk management theories may be combined to develop a decision support system aimed at improving the decision-making processes of contractors in tendering. However, this research has only concentrated on a particular aspect of competitive bidding (management of risks in refurbishment work in the London area). Thus, further research effort may be directed to investigate the management of risks in other aspects of competitive tendering as described below.

a) A similar approach may be adopted to investigate the risk management strategy and perception of refurbishment contractors in the United Kingdom construction industry generally. Comparative studies can thus be performed to determine how contractors perceive risks under different market conditions and regional conditions. Such investigation would greatly enhance the understanding of contractors and also provide useful guidelines in the formulation of marketing strategies.

b) Ditto in new-build contracts.

c) In recent years, the role of sub-contractors has increased significantly, particularly in the refurbishment industry. Quotations obtained from domestic sub-contractors have undue influence on the tender success rate and profit margin of main contractors. As such, it would be useful if a decision support or expert system could be set up to assist contractors to evaluate the risks involved in the selection of sub-contractors. Such a system would provide a more consistent and objective approach to risk management in the selection of sub-contractors.

d) This study has also found that risk factors pertaining to personnel relationship and tender documentation, and accuracy of cost estimates have significant influences on the risk perception of contractors. An in-depth investigation into methods of improving the tender documentation (in terms of standardisation of format and clarity of description of work), further use of computers to increase efficiency and accuracy of cost estimating and understanding of factors influencing the working relationships between contractor, client and consultant would be of paramount importance in reducing the risks involved in competitive tendering.

In conclusion, a knowledge base may also be incorporated into the proposed decision support and risk management system to develop an expert system for the management of risks in competitive bidding for refurbishment work.

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APPENDICES

APPENDIX A

SURVEY QUESTIONNAIRE AND REPERTORY GRID FORM

(i) Survey questionnaire for risk management in refurbishment work

Section A : Tender adjudication

1) Please rate the degree of importance given to the following variables during tender adjudication.

(Please tick one box in each row)

Variables	Degree of importance Low Importance						High Importance
	1	2	3	4	5	6	7
a) Type of job							
b) Size of job							
c) Job location							
d) Contract period							
e) Complexity of work							
f) Relationship with client							
g) Relationship with client's consultants							
h) Credit worthiness of client							
i) Type of contract							
j) Amendments to standard form							
k) Contractual liabilities							
l) Work load commitment of contractor							
m) Material,plant and labour availability							
n) Financial availability of contractor							
o) Management and expertise availability							
p) Accuracy of contractor's cost estimate							
q) Proportion of priceable building work							
r) Proportion of domestic sub-contractor's work							
s) Proportion of NSC / supplier's work							
t) Proportion of preliminaries							
u) Scope for claims							
v) Political conditions							
w) Economic conditions (job availability)							
x) Technological conditions							
y) Inflation							
z) Number of bidders							
aa) Identity of bidders							
ab) Other factors , please specify							
ac)							
ad)							

2) Is decision making during tender adjudication made by individual or group ?

	Individual
	Group

3) Arrange the following job types in order of difficulty in pricing with rank 1 assigned to the most difficult job type , rank 2 to the next most difficult job type etc.

Types of jobs	Rank Number
Transport and Utility	
Industrial	
Administration and Office	
Health and Welfare	
Refreshment and Entertainment	
Religious	
Education and Information	
Residential	

Section B : Risk management

4) Please rate the level of financial risk involved when pricing the following items in refurbishment work. (Tick one box in each row)

Variables	Level of Risk Low Risk						High Risk
	1	2	3	4	5	6	7
a) Protection of occupants / passer-by							
b) Protection of existing buildings							
c) Accessibility of work							
d) Noise and dust protection							
e) Supervision and co-ordination of work force							
f) Productivity of work force and plants							
g) Selection of labour							
h) Weather conditions							
i) Restrictions on working hours							
j) Removal of debris and rubbish							
k) Storage and handling of materials							
l) Security							
m) Programming of work							
n) "Matching up" refurbished work with existing							
o) Others, please specify							
p)							

5) Below are listed a number of strategies commonly adopted during tendering
Please indicate how frequently your firm uses the strategies.

(Tick one box in each row)

Variables	Frequency of Use Least Frequent						Very Frequent
	1	2	3	4	5	6	7
a) Risk avoidance - Return tender documents unpriced							
b) Risk avoidance - Pricing uncompetitive bid (cover bids)							
c) Risk reduction - Reduce risk through information gathering							
d) Risk reduction - Qualifying tender documents							
e) Risk transfer – Taking up insurance policies							
f) Risk transfer – Transferring risks to sub-contractors							
g) Risk retention - Provision of risk allowance in tender							
h) Risk retention - Taking all risks without any provisions							

Section C : General information

6) What is the average annual turnover of refurbishment work in your firm?

	Less than 20 million pounds
	Between 20 to 70 million pounds
	Over 70 million pounds

7) Is your firm a refurbishment specialist ?

	Yes
	No

8) How many years have the firm been in operation as a refurbishment contractor ?

	Less than 2 years
	Between 2 to 5 years
	Over 5 years

9) What is the average percentage of jobs won by the firm in bidding for refurbishment work.

percent

10) Does the firm perform any tender analysis to monitor its bidding performance and its competitors ?

	Yes
	No

If Yes, please state the frequency of use of the following sources of information.

(Tick one box in each row)

Sources of information	Frequency of Use Least Frequent						Very Frequent
	1	2	3	4	5	6	7
a) Grapevine information							
b) From past tender bids							
c) From Independent organisation (eg. Builders' conference)							
d) From informal contact with competitors							
e) Others, please specify							
f)							

11) Please state your professional training background.

	Architect
	Engineer
	Quantity Surveyor
	Builder
	Others, please specify

12) Would you agree to a personal interview ?

	Yes
	No

13) Position of respondent in firm.

	Chairman
	Managing director
	Estimator
	Others, please specify

(ii) Repertory Grid interview

(a) Questionnaire for repertory grid interview

1) What is the size of your firm ?

	Small
	Medium
	Large

2) What is the turnover of refurbishment work in your firm ?

	pounds

3) How many years has your firm been operating in refurbishment work ?

	years

4) What value of job size would you consider as small, medium or large contract.

	Small contract
	Medium contract
	Large contract

5) Is your firm a refurbishment specialist ?

	Yes
	No

6) What amount of money would be considered as high or low loss to the firm.

	High loss
	Low loss

7) Which type of building is your firm most experienced in refurbishing ?

8) Name of firm :

(b) Pre-determined constructs of repertory grid interview

Construct		Elements									Construct
		A	B	C	D	E	F	G	H		
Low accuracy in cost estimate											High Accuracy in cost estimate
Poor relationship with client											Good relationship with client
Poor relationship with consultants											Good relationship with consultants
Low workload of contractor											High workload of contractor
Low credit worthiness of client											High credit worthiness of client
Few bidders (3 or 4 bidders)											Many bidders (more than 5 bidders)
Small job size											Large job size
Low risk											High risk
Easy location of work											Difficult location of work
Low complexity											High complexity
Know identity of bidders											Do not know identity of bidders

1) Which of the project (A - H) is the most preferred bidding situation ?

2) Which of the project (A - H) is the least preferred bidding situation ?

3) Which of the project (A - H) is a typical bidding situation ?

(c) Repertory grid form

Random Element Sets			Construct		Elements									Construct
1	2	3			A	B	C	D	E	F	G	H		

APPENDIX B

BCIS TENDER INDICES

ABa3
Indices
December 1988
Superseding September 1988

Tender Price Indices 1983 todate ABa3

Quarter		1 Tender Price Index		2 Firm Price Index		3 Fluctuating Price Index	
		Index	No. in Sample	Index	No. in Sample	Index	No. in Sample
1983	i	213	78	220	50	199	28
	ii	214	65	216	40	211	25
	iii	213	61	214	36	209	25
	iv	219	50	226	31	206	19
1984	i	223	68	226	35	219	33
	ii	223	59	225	37	220	22
	iii	225	61	225	38	223	23
	iv	235	68	235	44	232	24
1985	i	233	81	237	54	224	27
	ii	246	60	250	40	236	20
	iii	241	82	242	67	232	15
	iv	250	53	253	44	230	9
1986	i	242	77	242	68	232	9
	ii	246	78	248	64	233	14
	iii	252	70	254	61	231	9
	iv	249	79	247	74	254	5
1987	i	260	87	258	83	264	4
	ii	257	87	255	79	262	8
	iii	259	93	258	87	251	6
	iv	279	81	277	76	297	5
1988	i	287	84	286	79	286	5
	ii	297	51	294	48	313	3
	iii	321	31	323	27	292	4
Forecast							
	iv	330		328	5		
1989	i	340					
	ii	349					
	iii	355					
	iv	360					
1990	i	368					
	ii	376					
	iii	379					
	iv	382					

Tender Price Index 1950-1974 see ABa8
Tender Price Index Forecast see ABa9
For a description of the indices see notes on ABa1

APPENDIX C

DERIVATION OF INTERQUARTILE RANGE AND RELATIVE DISPERSION (ATHOL KORABINSKI)

The interquartile range (or midspread as it is more commonly known now) can be considered as a measure of spread which is preferable to the standard deviation in the situation where sample sizes are small and outliers are a possible danger. It is robust or resistant against the effect of outliers.

If the quartiles are very carefully defined the interquartile range can be considered to be independent of the sample size and therefore the spread of projects with differing numbers of bids can be conveniently compared.

Denoting the lower and upper quartiles by Q_1 and Q_3, respectively, and the median by Q_2, then

interquartile range $IR = Q_3 - Q_1$, and

relative dispersion $RD = IR/Q_2$.

On the assumption that the given bids, denoted by

$$X_1 < X_2 < X_3 < \ldots\ldots\ldots\ldots < X_N,$$

are a random sample from a normal distribution with a mean μ and standard deviation σ, the expected value of IR is found to be $k\sigma$, where k can be determined from tables of expected values of normal order statistics

$$-1.1630,\ -0.4950,\ 0,\ +0.4950,\ +1.1630$$

Therefore

$$E(Q_1) = \mu + \frac{1}{4}[-1.1630 + 3(-0.4950)]\sigma = \mu - 0.662\sigma$$
$$E(Q_3) = \mu + \frac{1}{4}[3(0.4950) + 1.1630]\sigma = \mu + 0.662\sigma$$

Thus, $E(IR) = 1.324\sigma$, giving $k = 1.32$ to 2 decimal places, greater accuracy being unwarranted.

TABLE 2: VALUES OF $k = E(IR)/\sigma$

N	k
3	1.27
4	1.33
5	1.32
6	1.28
7	1.31
8	1.33
9	1.32
10	1.31

(1) Lindley, D.V. and Scott, W.F., New Cambridge Elementary Statistical Tables Cambridge University Press, 1984

(normal scores) [1]. Thus IR/k could be used to estimate σ. However it is found that by carefully defining the quartiles for the small sample sizes being used, namely N = 3, 4, ... 10. The value of k is almost constant. Therefore IR itself can be used for the purpose of comparing the spread of bids in projects with differing numbers of bidders.

Table 1 below shows how the quartiles are defined by interpolation between order statistics. The table is for N = 3,4,5 and 6 and is easily extended to the higher sample sizes of N = 7,8,...., as required.

TABLE 1: DEFINITION OF QUARTILES

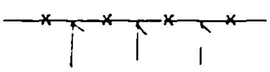
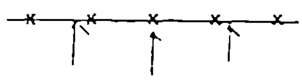
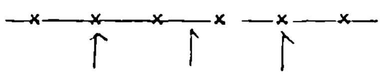
N	Illustration	Q_1	Q_2	Q_3
3		$\frac{3X_1 + X_2}{4}$	X_2	$\frac{X_2 + 3X_3}{4}$
4		$\frac{X_1 + X_2}{2}$	$\frac{X_2 + X_3}{2}$	$\frac{X_3 + X_4}{2}$
5		$\frac{X_1 + 3X_2}{4}$	X_3	$\frac{3X_4 + X_5}{4}$
6		X_2	$\frac{X_3 + X_4}{2}$	X_5

Table 2 below shows the resulting value of k, i.e. E(IR)/σ , for sample sizes N = 3,4,...., 10. To illustrate how k is calculated, consider the case of N = 5. From tables, the expected values of the normal scores are

APPENDIX D

ONE-WAY ANALYSIS OF VARIANCE AND SCHEFFE TEST OF BIDDING VARIABLES

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable NOBID number of bidders
Broken Down by YEAR year which bid is submitted

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
2	1984	1923	4.5677	1.3178	729.3207	421
3	1985	2533	4.8340	1.4334	1074.5553	524
4	1986	1287	5.1480	1.4829	547.5240	250
5	1987	2813	4.7277	1.4564	1259.8924	595
6	1988	1725	4.8050	1.3623	664.3510	359
7	1989	579	5.1696	1.3682	207.7768	112
Within Groups Total		10860	4.8032	1.4100	4483.4202	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	71.9969	5.	14.3994	7.2424	.0000
Within Groups	4483.4202	2255	1.9882		

Eta = .1267 Eta Squared = .0158

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDRANG
Broken Down by YEAR year which bid is submitted

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
2	1984	8085.22	19.2048	12.1985	62497.9230	421
3	1985	11270.83	21.5092	14.4541	109265.045	524
4	1986	4708.17	18.8327	12.1529	36775.3091	250
5	1987	12895.31	21.6728	14.8402	130817.197	595
6	1988	7083.58	19.7314	12.4405	55406.2907	359
7	1989	2561.86	22.8738	14.1229	22139.4948	112
Within Groups Total		46604.98	20.6126	13.5970	416901.260	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	3567.8773	5.	713.5755	3.8597	.0017
Within Groups	416901.2601	2255	184.8786		

Eta = .0921 Eta Squared = .0085

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDRD
Broken Down by YEAR year which bid is submitted

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
2	1984	4480.06	10.6415	6.8068	19460.8773	421
3	1985	6013.16	11.4755	8.0388	33797.3950	524
4	1986	2394.28	9.5771	6.3481	10034.2613	250
5	1987	6882.47	11.5472	8.1000	38972.2292	596
6	1988	3767.66	10.4949	6.5571	15392.4829	359
7	1989	1259.92	11.2493	6.2759	4371.9229	112
Within Groups Total		24797.55	10.9675	7.3563	122028.168	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	966.3317	5.	193.2663	3.5714	.0032 *
Within Groups	122028 1684	2255	54.1146		

Eta = .0886 Eta Squared = .0079

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDSPD
Broken Down by YEAR year which bid is submitted

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
2	1984	2464.93	5.8312	6 2613	16465.8462	421
3	1985	3176.16	6 0614	6 9010	24908 9321	524
4	1986	1361.30	5 4052	5 9036	8678 1654	250
5	1987	3902 69	6 5591	7.1574	30429 5049	596
6	1988	2359 07	6 5712	6 9974	17528 9140	359
7	1989	781 86	6 9808	7 9861	7077 5324	112
Within Groups Total		14026 00	6 2035	6 8265	105086 895	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	419 7293	5	83 9459	1 8013	1093
Within Groups	105086 8949	2255	46 6017		

Eta = 0631 Eta Squared = 0040

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable SKEW
Broken Down by YEAR year which bid is submitted

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
2	1984	29 73	0706	.6218	162 3946	421
3	1985	49 86	0951	6194	200 6235	524
4	1986	16 46	0658	5926	87 4367	250
5	1987	40 81	0684	6031	216 0726	596
6	1988	-21 80	- 0607	5737	117 8306	359
7	1989	- 69	- 0061	6369	45 0249	112
Within Groups Total		114 36	0506	6065	829 3818	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	6 2681	5	1 2536	3 4085	0045 *
Within Groups	829 3818	2255	3678		

Eta = 0866 Eta Squared = 0075

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   KURT
Broken Down by   YEAR

Value	Sum	Mean	Std Dev	Sum of Sq	Cases
2	-467.98	-1.1116	.5837	133.4771	421
3	-563.26	-1.0749	.6078	193.2211	524
4	-254.23	-1.0169	.5687	80.5264	250
5	-653.29	-1.0980	.5521	181.0851	595
6	-406.64	-1.1327	.5125	94.0258	359
7	-112.88	-1.0079	.5840	37 8636	112
Within Groups Total	-2458.29	-1.0873	.5651	720.1990	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	3.0821	5.	.6164	1.9300	.0863
Within Groups	720.1990	2255	.3194		

Eta = .0653   Eta Squared = .0043

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   NOBID   number of bidders
Broken Down by   JOBTYPE   type of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	Transport & Utility	588	4 8197	1 5213	280.0328	122
2	Industrial	320	4.8485	1 4277	132.4848	66
3	Administrative,offic	3027	4.7297	1 4088	1268.2359	640
4	Health & Welfare	866	4.9486	1.4671	374.5371	175
5	Refreshment,Entertai	532	4.7500	1.1968	159 0000	112
6	Religious	126	4.6667	1.2089	38.0000	27
7	Education,Scientific	1413	5 1196	1 5244	639 0543	276
8	Residential	3988	4 7307	1 3887	1623 8743	843
Within Groups Total		10860	4 8032	1 4157	4515 2193	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	40 1977	7	5.7425	2.8654	0056
Within Groups	4515 2193	2253	2 0041		

Eta = 0939   Eta Squared = 0088

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   BIDRANG
Broken Down by   JOBTYPE   type of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	Transport & Utility	2575 42	21 1100	16 4034	32567 6760	122
2	Industrial	1129 76	17 1176	10 6827	7417 8240	66
3	Administrative,offic	11623 75	18 1621	12 8181	104990 413	640
4	Health & Welfare	3500 74	20 0043	13 5617	32001 9739	175
5	Refreshment,Entertai	2101 75	18 7656	12 3761	17001 6860	112
6	Religious	576 30	21 3444	13 1022	4463 3257	27
7	Education,Scientific	5053 04	18 3081	11 9164	39050 0709	276
8	Residential	20044 22	23 7772	14 1227	167936 944	843
Within Groups Total		46604 98	20 6126	13 4144	405419 913	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	15049 2240	7	2149 8891	11 9474	0000
Within Groups	405419 9134	2253	179 9467		

Eta = 1892   Eta Squared = .0358

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDRD
Broken Down by JOBTYPE type of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	Transport & Utility	1306 24	10.7068	7.7602	7288.7877	122
2	Industrial	613.07	9.2889	5.4231	1911.8306	66
3	Administrative,offic	6212.23	9.7066	6.9054	30470.5643	640
4	Health & Welfare	1927.21	11.0126	6.9998	8525.5848	175
5	Refreshment,Entertai	1115.90	9.9634	6.1772	4235 4699	112
6	Religious	296.33	10.9753	7.5594	1485.7507	27
7	Education,Scientific	2588.93	9.3802	6.9347	13224.8881	276
8	Residential	10737.64	12.7374	7.7974	51192.6299	843
Within Groups Total		24797.55	10.9675	7 2472	118333.286	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	4661.2140	7.	665.8877	12.6781	.0000
Within Groups	118333.2860	2253	52.5225		

Eta = 1947   Eta Squared = .0379

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDSPD
Broken Down by JOBTYPE type of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	Transport & Utility	750 40	6 1508	8 3803	8497.7771	122
2	Industrial	372 32	5 6413	7 6767	3830 5551	66
3	Administrative,offic	3518 23	5 4972	6 2590	25033 0499	640
4	Health & Welfare	1056 33	6 0362	7 6120	10082 1095	175
5	Refreshment,Entertai	629 50	5 6206	6.1104	4144.3548	112
6	Religious	171 34	6 3460	5 3709	750 0028	27
7	Education,Scientific	1505 27	5 4539	5 5353	8425 8917	276
8	Residential	6022.60	7 1443	7 1842	43457.7736	843
Within Groups Total		14028 00	6 2035	6 8014	104221 615	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	1285 1097	7	183 5871	3 9687	0003
Within Groups	104221 6146	2253	46 2590		

Eta = 1104   Eta Squared = 0122

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable SKEW
Broken Down by JOBTYPE type of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	Transport & Utility	15 91	1304	5493	36 5122	122
2	Industrial	4 30	0651	5632	20 6209	66
3	Administrative,offic	41 82	0653	5991	229 3370	640
4	Health & Welfare	- 47	- 0027	5708	56 6881	175
5	Refreshment,Entertai	20 50	1830	5716	36 2686	112
6	Religious	5 61	2077	6860	12 2006	27
7	Education,Scientific	6 50	0236	6587	119 3006	276
8	Residential	20 20	0240	6164	319 8664	843
Within Groups Total		114 36	.0506	6072	830 7934	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	4 8566	7	6938	1 8814	0686
Within Groups	830 7934	2253	3687		

Eta = 0762   Eta Squared = 0068

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   KURT
Broken Down by   JOBTYPE

Value	Sum	Mean	Std Dev	Sum of Sq	Cases
1	-140.56	-1.1521	.5748	39.0748	122
2	-74.61	-1.1304	.6792	29.8947	66
3	-701.23	-1.0957	.5315	180.5412	640
4	-197.90	-1.1309	.4800	40.0819	175
5	-121.84	-1.0879	.5344	31.6957	112
6	-25.60	-.9483	.5880	8.9895	27
7	-270.30	-.9794	.6405	112.8137	276
8	-926.24	-1.0987	.5709	274.4270	843
Within Groups Total	-2458.29	-1.0873	.5647	718.4206	2261

Source	Sum of Squares	D.F	Mean Square	F	Sig.
Between Groups	4.8606	7.	.6944	2.1775	.0334
Within Groups	718.4206	2253	.3189		

Eta = .0820   Eta Squared = .0067

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   NOBID   number of bidders
Broken Down by   JOBSIZE   size of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	less than 100000	403	4.0300	.9791	94.9100	100
2	100000-250000	2163	4.2164	1.1241	644.9825	513
3	250000-500000	3139	4.6435	1.2853	1115.0814	676
4	500000-750000	1716	5.0769	1.3467	611.1509	338
5	750000-1000000	916	5.0889	1.4350	368.5778	180
6	1000000-1250000	766	5.3194	1.3309	253.3056	144
7	1250000-1500000	442	5.6667	1.8130	253.3333	78
8	1500000-1750000	301	5.5741	1.6438	143.2037	54
9	1750000-2000000	222	5.5500	1.7090	113.9000	40
10	2000000-2250000	187	5.1944	1.3484	63.6389	36
11	2250000-2500000	131	5.9545	1.5880	52.9545	22
12	2500000-2750000	68	6.1818	1.4013	19.6364	11
13	2750000-3000000	105	5.5263	1.4470	38.7368	19
14	more than 3000000	302	6.0400	1.9894	193.9200	50
Within Groups Total		10860	4.8032	1.3291	3949.3317	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	584.0864	13	45.0836	25.5213	.0000
Within Groups	3949.3317	2247	1.7575		

Eta = .3587   Eta Squared = .1287

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   BIDRANG
Broken Down by   JOBSIZE   size of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	less than 100000	3036.91	30.3691	14.8543	21844.2770	100
2	100000-250000	12740.10	24.8346	16.4642	138419.826	513
3	250000-500000	13778.52	20.3795	12.3538	103018.365	676
4	500000-750000	6358.26	18.8114	12.6819	54029.1064	338
5	750000-1000000	3169.00	17.6056	10.5414	19890.6005	180
6	1000000-1250000	2602.64	18.0732	11.9914	20562.5090	144
7	1250000-1500000	1477.62	18.9438	13.0746	13162.5904	78
8	1500000-1750000	849.44	15.7304	8.5429	3867.9703	54
9	1750000-2000000	529.45	13.2363	7.9316	2453.4443	40
10	2000000-2250000	592.39	16.4552	7.8990	2183.7989	36
11	2250000-2500000	388.01	17.6367	7.7354	1256.5548	22
12	2500000-2750000	158.80	14.4361	6.5924	434.5909	11
13	2750000-3000000	274.98	14.4726	11.5455	2399.3893	19
14	more than 3000000	652.07	13.0414	10.9869	5914.9071	50
Within Groups Total		46604.98	20.6126	13.1682	389635.899	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	30833.2382	13	2371.7876	13.6779	.0000
Within Groups	389635.8992	2247	173.4027		

Eta = .2708   Eta Squared = .0733

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDAD
Broken Down by JOBSIZE size of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	less than 100000	1706.84	17 0684	7 8414	6087.3109	100
2	100000-250000	7022.86	13 6898	8 6382	38204.2456	513
3	250000-500000	7486.02	11 0740	6.8078	31284.0679	676
4	500000-750000	3227.53	9 5489	6 1422	12714.0421	338
5	750000-1000000	1659.32	9 2184	6 0306	6509.9594	180
6	1000000-1250000	1335.03	9 2710	7.0111	7029.1847	144
7	1250000-1500000	652.88	8 3702	5.9481	2724.2111	78
8	1500000-1750000	427.18	7 9107	3.8729	794.9324	54
9	1750000-2000000	237.07	5 9268	3.4642	468.0193	40
10	2000000-2250000	328.28	9 1183	5.4648	1046 2427	36
11	2250000-2500000	191.10	8.6862	5.0227	529.7774	22
12	2500000-2750000	70.22	6.3836	3.6012	129.6899	11
13	2750000-3000000	148.88	7.8360	6.3903	735.0367	19
14	more than 3000000	304.37	6.0873	5 8364	1669 0663	50
Within Groups Total		24797.56	10 9675	6.9943	109924.806	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	13049 6937	13	1003 8411	20 5508	0000
Within Groups	109924.8063	2247	48.9207		

Eta = .3260   Eta Squared = .1063

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDSPD
Broken Down by JOBSIZE size of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	less than 100000	946 69	9 4669	7 4638	5500 2839	100
2	100000-250000	4370 52	8 5196	9 2133	43461 2970	513
3	250000-500000	4257 29	6 2978	6 1490	25521 9789	676
4	500000-750000	1763 79	5 1887	5 6401	10720 0327	338
5	750000-1000000	784 21	4 3567	4 2189	3182 9976	180
6	1000000-1250000	578 20	4 0152	3 9580	2240 1897	144
7	1250000-1500000	439 00	5 6282	6 8633	3616 5162	78
8	1500000-1750000	241 01	4 4631	4 3962	1024 3213	54
9	1750000-2000000	156 39	3 9098	4 0779	648 5460	40
10	2000000-2250000	124 46	3 4573	2 1183	157 0588	36
11	2250000-2500000	113 91	5 1779	5 9621	746 4677	22
12	2500000-2750000	36 16	3 2873	3 7201	138 3916	11
13	2750000-3000000	67 38	3 5466	3 4960	220 0023	19
14	more than 3000000	158 09	3 1618	5 4898	1478 7620	50
Within Groups Total		14026 00	6 2036	6 6261	98454 8367	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	6651 7886	13	527 0607	12 0046	0000
Within Groups	98454 8367	2247	43 9061		

Eta = 2648   Eta Squared = 0649

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable SKEW
Broken Down by JOBSIZE size of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	less than 100000	8 96	0896	5265	27 4451	100
2	100000-250000	24 41	0476	5647	163 2890	513
3	250000-500000	13 89	0206	5850	230 9742	676
4	500000-750000	14 19	0420	6428	139 2306	338
5	750000-1000000	19 29	1072	6085	66 2803	180
6	1000000-1250000	18 84	1308	6553	61 4088	144
7	1250000-1500000	4 58	0587	7615	44 6552	78
8	1500000-1750000	- 71	- 0131	5964	18 8497	54
9	1750000-2000000	-2 68	- 0669	7137	19 8637	40
10	2000000-2250000	4 58	1271	5733	11 5054	36
11	2250000-2500000	- 57	- 0258	7718	12 5104	22
12	2500000-2750000	2 39	2171	8913	7 9433	11
13	2750000-3000000	96	0501	5465	5 3766	19
14	more than 3000000	6 25	1250	6753	22 3466	50
Within Groups Total		114 36	0506	6084	831 6589	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	3 9909	13.	.3070	8295	6289
Within Groups	831 6589	2247	3701		

Eta = 0691   Eta Squared = .0048

ANALYSIS OF VARIANCE

Criterion Variable KURT
Broken Down by JOBSIZE

Value	Sum	Mean	Std Dev	Sum of Sq	Cases
1	-123.68	-1.2368	.3876	14.8721	100
2	-630.33	-1.2287	.4467	101.7200	513
3	-761.28	-1.1262	4962	166.5134	676
4	-348.21	-1.0302	.5932	118.5724	338
5	-186.79	-1.0322	.5983	64.0750	180
6	-138.66	-.9628	.7018	70.4263	144
7	-56.72	-.7272	.8816	59.8474	78
8	-56 38	-1.0441	.5788	17 7530	54
9	-31.03	-.7758	.6419	16.0692	40
10	-37.97	-1.0546	.5644	11.1506	36
11	-18.56	-.8436	.6541	8 9835	22
12	-6.29	-.5716	.9502	9.0296	11
13	-21.76	-1.1447	.5601	6.4462	19
14	-41.65	-.8330	.6509	20.7600	50
Within Groups Total	-2458.29	-1.0873	5618	684.2186	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	39 0625	13.	3.0048	9 8679	0000
Within Groups	684 2186	2247	.3045		

Eta = 2324 Eta Squared = .0540

ANALYSIS OF VARIANCE

Criterion Variable NOBID number of bidders
Broken Down by CLIENT type of client

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	public	5278	5 0123	1 5201	2430 8395	1053
2	private	5582	4 6209	1 2995	2038 3543	1208
Within Groups Total		10860	4 8032	1 4066	4469 1938	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	86 2233	1	86 2233	43 5824	0000
Within Groups	4469 1938	2259	1 9784		

Eta = 1376 Eta Squared = 0189

ANALYSIS OF VARIANCE

Criterion Variable BIDRANG
Broken Down by CLIENT type of client

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	public	21544 39	20 4600	13 3195	186635 420	1053
2	private	25060 59	20 7455	13 9174	233787 856	1208
Within Groups Total		46604 98	20 6126	13 6422	420423 276	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	45 8613	1	45 8613	2464	6197
Within Groups	420423 2760	2259	186 1103		

Eta = 0104 Eta Squared = 0001

ANALYSIS OF VARIANCE

Criterion Variable BIDRD
Broken Down by CLIENT type of client

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	public	11425.88	10.8508	7.2939	55966.8557	1053
2	private	13371.67	11.0693	7.4605	67000.7921	1208
Within Groups Total		24797.55	10.9675	7.3780	122967.648	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	26.8522	1.	26.8522	.4933	.4825
Within Groups	122967.6478	2259	54.4346		

Eta = .0148 Eta Squared = .0002

ANALYSIS OF VARIANCE

Criterion Variable BIDSPD
Broken Down by CLIENT type of client

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	public	6073.35	5.7677	6.3287	42134.7359	1053
2	private	7952.65	6 5833	7 2246	62997.5972	1208
Within Groups Total		14026.00	6 2035	6 8220	105132.333	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig
Between Groups	374 2911	1.	374 2911	8 0425	0046
Within Groups	105132 3331	2259	46 5393		

Eta = 0596 Eta Squared = 0035

ANALYSIS OF VARIANCE

Criterion Variable SKEW
Broken Down by CLIENT type of client

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
1	public	70 07	0665	5999	378 5781	1053
2	private	44 29	0367	6150	456 5694	1208
Within Groups Total		114.36	0506	6080	835.1475	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	.5024	1.	5024	1 3590	2438
Within Groups	835.1475	2259	3697		

Eta = 0246 Eta Squared = .0006

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   KURT
Broken Down by   CLIENT

Value	Sum	Mean	Std Dev	Sum of Sq	Cases
1	-1131.36	-1.0744	.5869	361.1649	1053
2	-1326.92	-1.0984	.5475	361.7916	1208
Within Groups Total	-2458.29	-1.0873	.5657	722.9564	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	.3247	1.	.3247	1.0146	.3139
Within Groups	722.9564	2259	.3200		

Eta = .0212   Eta Squared = .0004

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   NOBID   number of bidders
Broken Down by   LOCATION   location of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
4	Inner and Outer Lond	7722	4.7028	1.3599	3034.9671	1642
5	Outside London	3138	5.0695	1.5370	1460 0129	619
Within Groups Total		10860	4.8032	1 4106	4494.9800	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	60 4370	1	60 4370	30 3733	0000
Within Groups	4494.9800	2259	1 9898		

Eta = 1152   Eta Squared = 0133

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   BIDRANG
Broken Down by   LOCATION   location of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
4	Inner and Outer Lond	34759 70	21 1691	13 8960	316874.274	1642
5	Outside London	11845 28	19 1362	12 8305	101736.960	619
Within Groups Total		46604 98	20 6126	13 6128	418611.234	2261

Source	Sum of Squares	D.F	Mean Square	F	Sig.
Between Groups	1857 9031	1.	1857 9031	10 0260	.0016
Within Groups	418611.2342	2259	185.3082		

Eta = .0665   Eta Squared = 0044

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDRD
Broken Down by LOCATION location of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
4	Inner and Outer Lond	18728.08	11.4056	7.6007	94801.2143	1642
5	Outside London	6069.47	9.8053	6.6149	27041.9468	619
Within Groups Total		24797.55	10.9675	7.3442	121843.161	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	1151.3390	1.	1151.3390	21.3461	.0000
Within Groups	121843.1610	2259	53.9368		

Eta = .0968 Eta Squared = .0094

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable BIDSPD
Broken Down by LOCATION location of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
4	Inner and Outer Lond	10529 94	6 4129	6 8073	76042.6852	1642
5	Outside London	3496.07	5 6479	6.8739	29200.8991	619
Within Groups Total		14026 00	6 2035	6 8256	105243.584	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	263 0399	1	263 0399	5 6460	0176
Within Groups	105243 5843	2259	46 5886		

Eta = 0499 Eta Squared = 0025

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable SKEW
Broken Down by LOCATION location of job

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
4	Inner and Outer Lond	80 05	0488	6052	601 0709	1642
5	Outside London	34.31	.0554	6161	234 5590	619
Within Groups Total		114 36	0506	6082	835 6299	2261

Source	Sum of Squares	D.F	Mean Square	F	Sig
Between Groups	.0200	1.	0200	0540	8163
Within Groups	835 6299	2259	3699		

Eta = 0049 Eta Squared = .0000

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   KURT
Broken Down by   LOCATION

Value	Sum	Mean	Std Dev	Sum of Sq	Cases
4	-1816.17	-1.1061	.5585	511.9404	1642
5	-642.12	-1.0373	.5818	209.2176	619
Within Groups Total	-2458.29	-1.0873	.5650	721.1581	2261

Source	Sum of Squares	D.F.	Mean Square	F	Sig.
Between Groups	2.1230	1.	2.1230	6.6502	.0100
Within Groups	721.1581	2259	.3192		

Eta = .0542   Eta Squared = .0029

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   BIDRANG
Broken Down by   NOBID   number of bidders

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
3	three bidders	8788 38	18 4630	14 0005	93107.0200	476
4	four bidders	10844.68	20 3084	13 5254	97504.4903	534
5	five bidders	12752.52	21 9871	14.4003	120066.906	580
6	six bidders	9642.50	21.2056	13.1584	77741.0258	460
7	seven bidders	2513.82	20 6051	11 3601	15615 4066	122
8	eight bidders	1469 69	23.5434	12 9439	10220.2470	62
9	nine bidders	472.35	19 6813	8 3588	1607.0074	24
10	ten bidders	231 04	17 7724	6.1023	446 8570	13
Within Groups Total		46604.98	20 6126	13 5934	416307.959	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	4161.1786	7	594 4541	3 2171	0021
Within Groups	416307 9587	2253	184 7794		

Eta = 0996   Eta Squared = 0099

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   BIDRD
Broken Down by   NOBID   number of bidders

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
3	three bidders	5812 97	12 2121	8 4688	33986 9172	476
4	four bidders	6307 60	11 8120	7 4313	29434 8838	534
5	five bidders	6282 02	10 8311	7 2741	30636 4984	580
6	six bidders	4377 89	9 7286	6 4261	18641.1796	450
7	seven bidders	1150 69	9 4319	6 6260	5312 4476	122
8	eight bidders	584 07	9 4205	5 2374	1673 2411	62
9	nine bidders	207 47	8 6446	5 3079	647 9985	24
10	ten bidders	74 83	5 7558	1.3865	23 0339	13
Within Groups Total		24797 56	10 9675	7 3059	120258 200	2261

Source	Sum of Squares	D F	Mean Square	F	Sig.
Between Groups	2738.3002	7	391 1857	7 3289	0000
Within Groups	120258 1998	2253	53 3760		

Eta = .1492   Eta Squared = 0223

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   BIDSPD
Broken Down by   NOBID   number of bidders

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
3	three bidders	4240.83	8.9093	9.4638	42542.7025	476
4	four bidders	3410.29	6.3863	6.1306	20032.2529	534
5	five bidders	3340.10	5.7588	6.4639	24191.4189	580
6	six bidders	2188.52	4.8589	4.0949	10758.0261	450
7	seven bidders	461.13	3.7798	2.9612	1053.8346	122
8	eight bidders	269.83	4.3521	4.1565	1053.8784	62
9	nine bidders	74.35	3.0978	2.1569	106.8977	24
10	ten bidders	42.95	3.3036	2.3551	66.5563	13
Within Groups Total		14026.00	6.2035	6.6557	99806.5666	2261

Source	Sum of Squares	D.F	Mean Square	F	Sig.
Between Groups	5701.0577	7.	814.4368	18.3860	.0000
Within Groups	99806 5666	2253	44.2990		

Eta = 2325   Eta Squared = 0540

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   SKEW
Broken Down by   NOBID   number of bidders

Value	Label	Sum	Mean	Std Dev	Sum of Sq	Cases
3	three bidders	9 18	0193	4974	117 5385	476
4	four bidders	17 93	0336	5643	169 7144	534
5	five bidders	44 60	0769	6659	256.7189	580
6	six bidders	24.61	0547	6673	199 9381	450
7	seven bidders	12.15	0996	.6274	47 6251	122
8	eight bidders	3.97	0640	6729	27 6203	62
9	nine bidders	82	0342	5321	6 5108	24
10	ten bidders	1 11	0853	8479	8.6279	13
Within Groups Total		114 36	0506	6085	834 2941	2261

Source	Sum of Squares	D F	Mean Square	F	Sig
Between Groups	1 3558	7	1937	5230	8177
Within Groups	834 2941	2263	3703		

Eta = 0403   Eta Squared = 0016

A N A L Y S I S   O F   V A R I A N C E

Criterion Variable   KURT
Broken Down by   NOBID

Value	Sum	Mean	Std Dev	Sum of Sq	Cases
3	-714 54	-1 5011	0175	1462	476
4	-657 32	-1 2309	3569	67 8742	534
5	-546 15	- 9416	5316	163 6540	580
6	-387 62	- 8614	6427	186 4377	450
7	-93 61	- 7673	7128	61 4780	122
8	-39 77	- 6415	8859	47 8792	62
9	-17 58	- 7325	7126	11 6779	24
10	-1 70	- 1310	1 2107	17 5901	13
Within Groups Total	-2458 29	-1 0873	4967	555 7372	2261

Source	Sum of Squares	D.F	Mean Square	F	Sig
Between Groups	167 5438	7	23 9348	97 0336	0000
Within Groups	555 7372	2263	2467		

Eta = 4813   Eta Squared = 2316

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      Variable  NOBID        number of bidders
   By Variable  YEAR         year which bid is submitted

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          4.71   4.71   4.71   4.71   4.71
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        0.9970 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                        G G G G G G
                        r r r r r r
                        p p p p p p

    Mean       Group    2 5 6 3 4 7

    4.5677     Grp 2
    4.7277     Grp 5
    4 8060     Grp 6
    4.8340     Grp 3
    5 1480     Grp 4    * *
    5 1896     Grp 7    *
```

```
    Variable  BIDRD
    By Variable  YEAR        year which bid is submitted

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0 050 LEVEL -

          4 71   4.71   4 71   4 71   4 71
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS
        5 2015 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0 050 LEVEL


                        G G G G G G
                        r r r r r r
                        p p p p p p

    Mean       Group    4 6 2 7 3 5

     9 5771    Grp 4
    10 5184    Grp 6
    10 6415    Grp 2
    11 2493    Grp 7
    11 4755    Grp 3    *
    11 5672    Grp 5    *
```

```
    Variable  SKEW
  By Variable  YEAR        year which bid is submitted

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0 050 LEVEL -

          4 71   4 71   4 71   4 71   4 71
THE RANGES ABOVE ARE TABLE RANGES
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS
        0 4288 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0 050 LEVEL


                        G G G G G G
                        r r r r r r
                        p p p p p p

    Mean       Group    6 7 4 5 2 3

    - 0596     Grp 6
    - 0061     Grp 7
      0668     Grp 4
      0686     Grp 5
      0706     Grp 2
      0951     Grp 3    *
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     Variable  NOBID       number of bidders
   By Variable  JOBTYPE    type of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          5.31   5.31   5.31   5.31   5.31   5.31   5.31
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        1.0010 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                        G G G G G G G G
                        r r r r r r r r
                        p p p p p p p p

     Mean      Group    6 3 8 5 1 2 4 7

     4.6667    Grp 6
     4.7297    Grp 3
     4.7307    Grp 8
     4.7500    Grp 5
     4.8197    Grp 1
     4.8486    Grp 2
     4.9486    Grp 4
     5.1190    Grp 7      * *


     Variable  BIDRANG
   By Variable  JOBTYPE    type of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          5.31   5.31   5.31   5.31   5.31   5.31   5.31
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        9.4825 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                        G G G G G G G G
                        r r r r r r r r
                        p p p p p p p p

     Mean      Group    2 3 7 5 4 1 6 8

    17.1176    Grp 2
    18.1621    Grp 3
    18.3081    Grp 7
    18.7656    Grp 5
    20.0043    Grp 4
    20.9912    Grp 1
    21.3446    Grp 6
    23.7772    Grp 8      * * *


     Variable  BIDSPD
   By Variable  JOBTYPE    type of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          5.31   5.31   5.31   5.31   5.31   5.31   5.31
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        4.8093 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                        G G G G G G G G
                        r r r r r r r r
                        p p p p p p p p

     Mean      Group    7 3 5 2 4 1 6 8

     5.4539    Grp 7
     5.4972    Grp 3
     5.6205    Grp 5
     5.6413    Grp 2
     6.0362    Grp 4
     6.1508    Grp 1
     6.3460    Grp 6
     7.1443    Grp 8      *
```

```
      Variable  BIDRD
   By Variable  JOBTYPE    type of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          5.31   5.31   5.31   5.31   5.31   5.31   5.31
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
       5.1243 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                            G G G G G G G G
                            r r r r r r r r
                            p p p p p p p p

      Mean       Group      2 7 3 5 1 6 4 8

      9.2889     Grp 2
      9.3802     Grp 7
      9.7068     Grp 3
      9.9634     Grp 5
     10.7761     Grp 1
     10.9753     Grp 6
     11.0126     Grp 4
     12.7374     Grp 8        * * *


      Variable  NOBID       number of bidders
   By Variable  JOBSIZE     size of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70
          6.70   6.70   6.70
THE RANGES ABOVE ARE TABLE RANGES
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
       0.9398 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                            G G G G G G G G G G G G G G
                            r r r r r r r r r r r r r r
                            p p p p p p p p p p p p p p
                                      1   1       1 1 1
      Mean       Group      1 2 3 4 5 0 6 3 9 8 7 1 4 2

      4.0300     Grp 1
      4.2164     Grp 2
      4.6435     Grp 3        *
      5.0740     Grp 4      * * *
      5.0889     Grp 5      * *
      5.1944     Grp10
      5.3194     Grp 6      * * *
      5.5263     Grp13
      5.5600     Grp 9      * *
      5.5741     Grp 8      * * *
      5.6667     Grp 7      * * *
      5.9545     Grp11      * *
      6.0400     Grp14      * * * *
      6.1818     Grp12      * *

      Variable  BIDRANG
   By Variable  JOBSIZE     size of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70
          6.70   6.70   6.70
THE RANGES ABOVE ARE TABLE RANGES
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS
       9.3076 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                            G G G G G G G G G G G G G G
                            r r r r r r r r r r r r r r
                            p p p p p p p p p p p p p p
                            1   1 1   1   1
      Mean       Group      4 9 2 3 8 0 5 1 6 4 7 3 2 1

     13.0414     Grp14
     13.2363     Grp 9
     14.4381     Grp12
     14.4724     Grp13
     15.7304     Grp 8
     16.4562     Grp10
     17.8055     Grp 5
     17.6367     Grp11
     18.0732     Grp 6
     18.7686     Grp 4
     18.9426     Grp 7
     20.3798     Grp 3
     24.8346     Grp 2      * *     *   *   * *   *
     30.3691     Grp 1      * *   * * * *   * * * *
```

```
     Variable  BIDRD
   By Variable  JOBSIZE     size of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0.050 LEVEL -

          6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70   6.70
          6.70   6.70   6.70
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        4.9459 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                        G G G G G G G G G G G G G G
                        r r r r r r r r r r r r r r
                        p p p p p p p p p p p p p p
                          1 1 1     1 1
    Mean       Group    9 4 2 3 8 7 1 0 5 6 4 3 2 1

    5.9268     Grp 9
    6.0873     Grp14
    6.3836     Grp12
    7.8360     Grp13
    7.9107     Grp 8
    8.3702     Grp 7
    8.6862     Grp11
    9.1183     Grp10
    9 2184     Grp 5
    9.2710     Grp 6
    9.5739     Grp 4
   11.0740     Grp 3      *
   13.6898     Grp 2    * *     * *     * * * *
   17.0684     Grp 1    * * * * * * * * * * * *




     Variable  BIDSPD
   By Variable  JOBSIZE     size of job

 MULTIPLE RANGE TEST


 SCHEFFE PROCEDURE
 RANGES FOR THE 0 050 LEVEL -

          6.70   6.70   6 70   6.70   6.70   6 70   6.70   6.70   6.70   6 70
          6.70   6.70   6.70
THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        4 6854 * RANGE * DSQRT(1/N(I) + 1/N(J))
   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0 050 LEVEL


                        G G G G G G G G G G G G G G
                        r r r r r r r r r r r r r r
                        p p p p p p p p p p p p p p
                        1 1 1 1         1
    Mean       Group    4 2 0 3 9 6 5 8 1 4 7 3 2 1

    3.1618     Grp14
    3.2873     Grp12
    3.4573     Grp10
    3.5465     Grp13
    3.9098     Grp 9
    4.0152     Grp 6
    4.3567     Grp 5
    4.4631     Grp 8
    5.1779     Grp11
    5.1887     Grp 4
    5 6282     Grp 7
    6.2978     Grp 3
    8.5195     Grp 2    *         * *     *   *
    9.4559     Grp 1    *         * *     *
```

Variable KURT
By Variable JOBSIZE size of job

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

6.70 6.70 6.70 6.70 6.70 6.70 6.70 6.70 6.70 6.70
6.70 6.70 6.70

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
0.3902 * RANGE * DSQRT(1/N(I) + 1/N(J))
(*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

Mean	Group	Grp 1	Grp 2	Grp13	Grp 3	Grp10	Grp 8	Grp 5	Grp 4	Grp 6	Grp11	Grp14	Grp 9	Grp 7	Grp12
-1.2368	Grp 1														
-1.2287	Grp 2														
-1.1447	Grp13														
-1.1262	Grp 3														
-1.0546	Grp10														
-1.0441	Grp 8														
-1.0322	Grp 5														
-1.0302	Grp 4		*												
-.9628	Grp 6		*												
-.8436	Grp11														
-.8330	Grp14		*												
-.7758	Grp 9		*												
-.7272	Grp 7	*	*		*										
-.5715	Grp12														

Variable BIDRD
By Variable NOBID number of bidders

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

5.31 5.31 5.31 5.31 5.31 5.31 5.31

THE RANGES ABOVE ARE TABLE RANGES
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
5.1657 * RANGE * DSQRT(1/N(I) + 1/N(J))
(*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

Mean	Group	Grp10	Grp 9	Grp 8	Grp 7	Grp 6	Grp 5	Grp 4	Grp 3
5.7558	Grp10								
8.6446	Grp 9								
9.4205	Grp 8								
9.4319	Grp 7								
9.7286	Grp 6								
10.8456	Grp 5								
11.8120	Grp 4					*			
12.2121	Grp 3					*			

```
       Variable  BIDRANG
     By Variable  NOBID        number of bidders

   MULTIPLE RANGE TEST


   SCHEFFE PROCEDURE
   RANGES FOR THE 0.050 LEVEL -

           5.31   5.31   5.31   5.31   5.31   5.31   5.31
  THE RANGES ABOVE ARE TABLE RANGES.
  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
          9.6094 * RANGE * DSQRT(1/N(I) + 1/N(J))
    (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                            G G G G G G G G
                            r r r r r r r r
                            p p p p p p p p
                            1
      Mean       Group      0 3 9 4 7 6 5 8

     17.7724     Grp10
     18.4630     Grp 3
     19.6813     Grp 9
     20.3084     Grp 4
     20.6051     Grp 7
     21.2056     Grp 6
     21.9621     Grp 5        *
     23.5434     Grp 8


       Variable  BIDSPD
     By Variable  NOBID        number of bidders

   MULTIPLE RANGE TEST


   SCHEFFE PROCEDURE
   RANGES FOR THE 0.050 LEVEL -

           5.31   5.31   5.31   5.31   5.31   5.31   5.31
  THE RANGES ABOVE ARE TABLE RANGES
  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
          4.7063 * RANGE * DSQRT(1/N(I) + 1/N(J))
    (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                            G G G G G G G G
                            r r r r r r r r
                            p p p p p p p p
                              1
      Mean       Group      9 0 7 8 6 5 4 3

      3.0978     Grp 9
      3.3036     Grp10
      3.7796     Grp 7
      4.3521     Grp 8
      4.8589     Grp 6
      5.7588     Grp 5
      6.3863     Grp 4          *
      8.9093     Grp 3      *   * * * * *


       Variable  KURT
     By Variable  NOBID        number of bidders

   MULTIPLE RANGE TEST


   SCHEFFE PROCEDURE
   RANGES FOR THE 0.050 LEVEL -

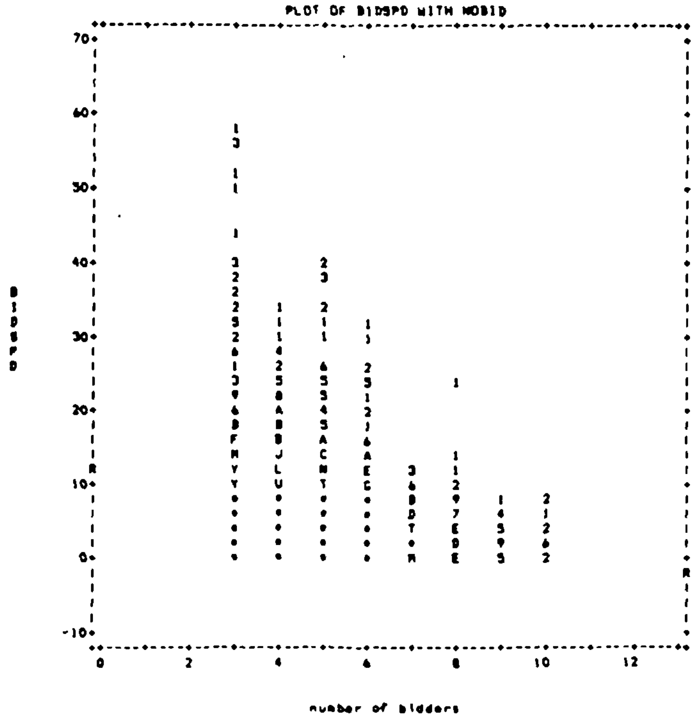
           5.31   5.31   5.31   5.31   5.31   5.31   5.31
  THE RANGES ABOVE ARE TABLE RANGES
  THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS
          0.3512 * RANGE * DSQRT(1/N(I) + 1/N(J))
    (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL


                            G G G G G G G G
                            r r r r r r r r
                            p p p p p p p p
                                          1
      Mean       Group      3 4 5 6 7 9 8 0

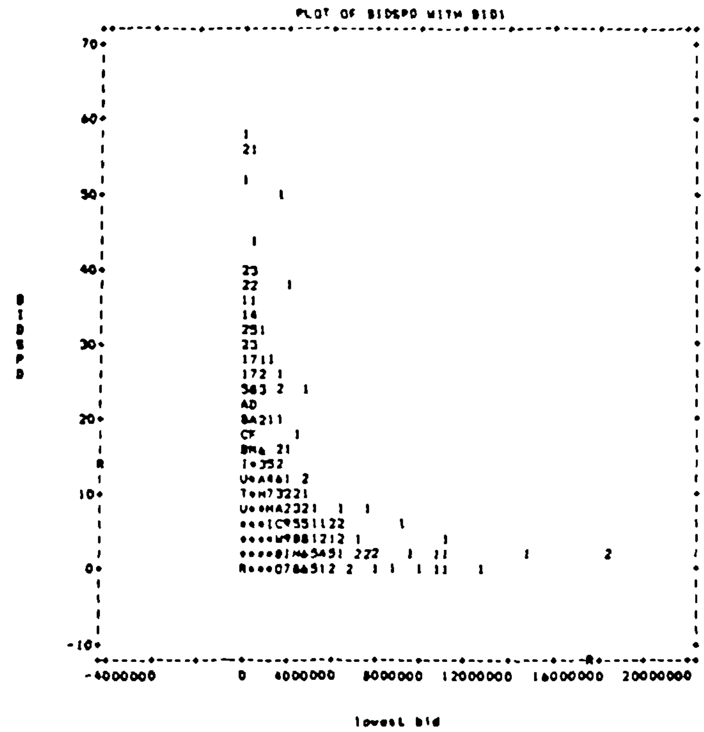
     -1.5011     Grp 3
     -1.2309     Grp 4      *
      -.9416     Grp 5      * *
      -.8614     Grp 6      * *
      -.7873     Grp 7      * *
      -.7325     Grp 9      * *
      -.6415     Grp 8      * * *
      -.1310     Grp10      * * * * *
```

APPENDIX E

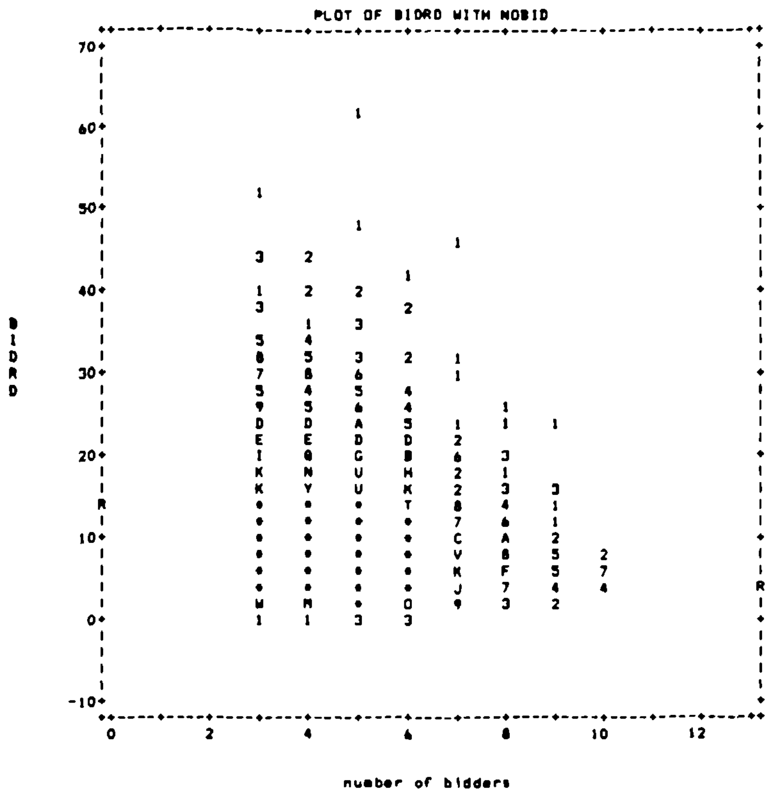
SCATTERPLOTS OF BIDDING VARIABLES



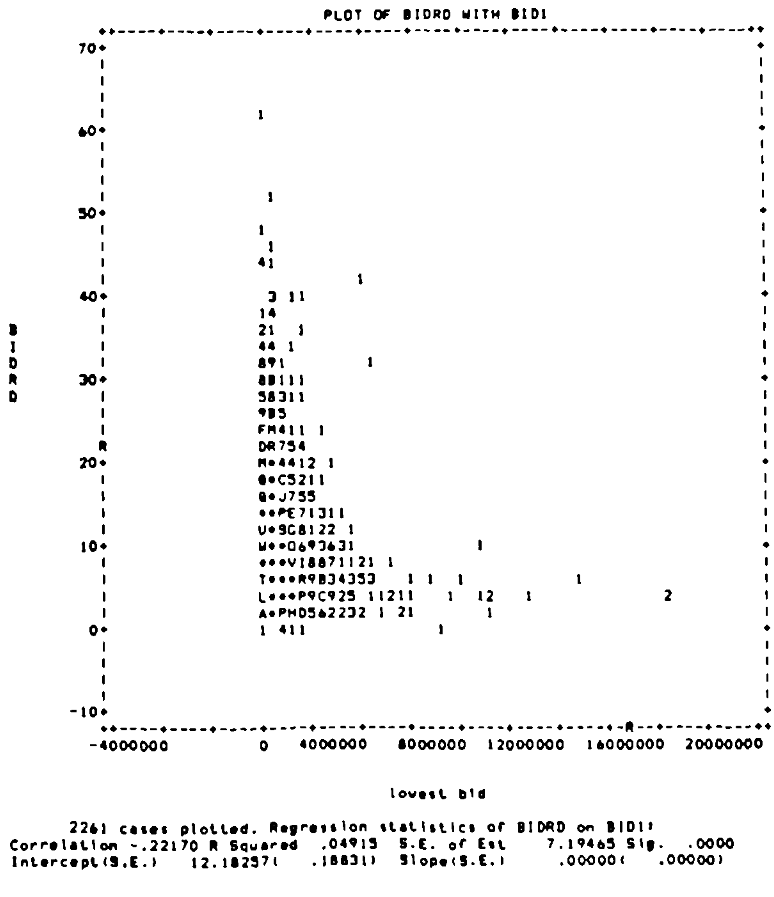
2261 cases plotted. Regression statistics of BIDSPD on NOBID:
Correlation -.21443 R Squared .04598 S.E. of Est 6.67514 Sig. .0000
Intercept(S.E.) 11.16015(.49534) Slope(S.E.) -1.03196(.09890)



2261 cases plotted. Regression statistics of BIDSPD on BID1:
Correlation -.17077 R Squared .02916 S.E. of Est 6.73372 Sig. .0000
Intercept(S.E.) 7.06769(.17624) Slope(S.E.) .00000(.00000)

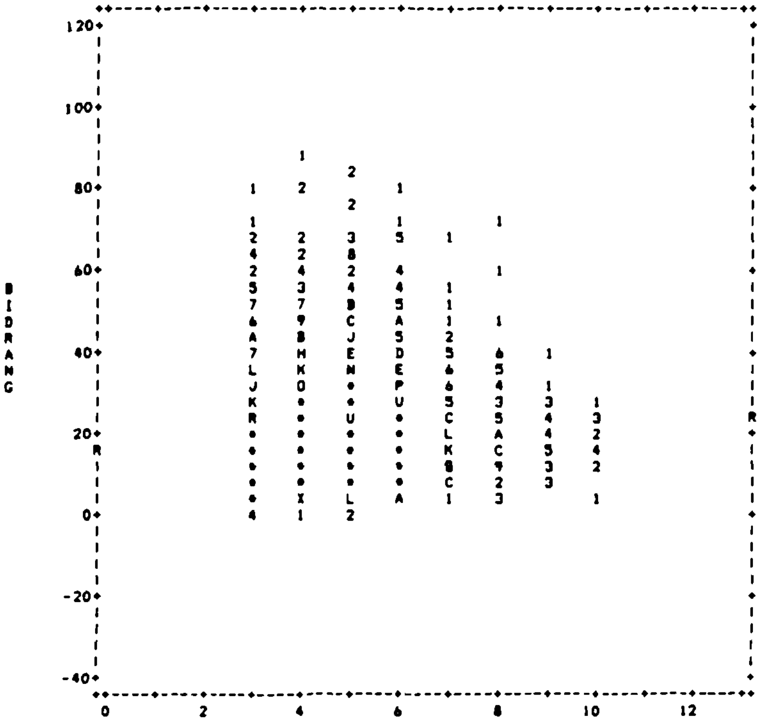


2261 cases plotted. Regression statistics of BIDRD on NOBID:
Correlation -.14432 R Squared .02083 S.E. of Est 7.30102 Sig. .0000
Intercept(S.E.) 14.57288(.54179) Slope(S.E.) -.74984(.10817)



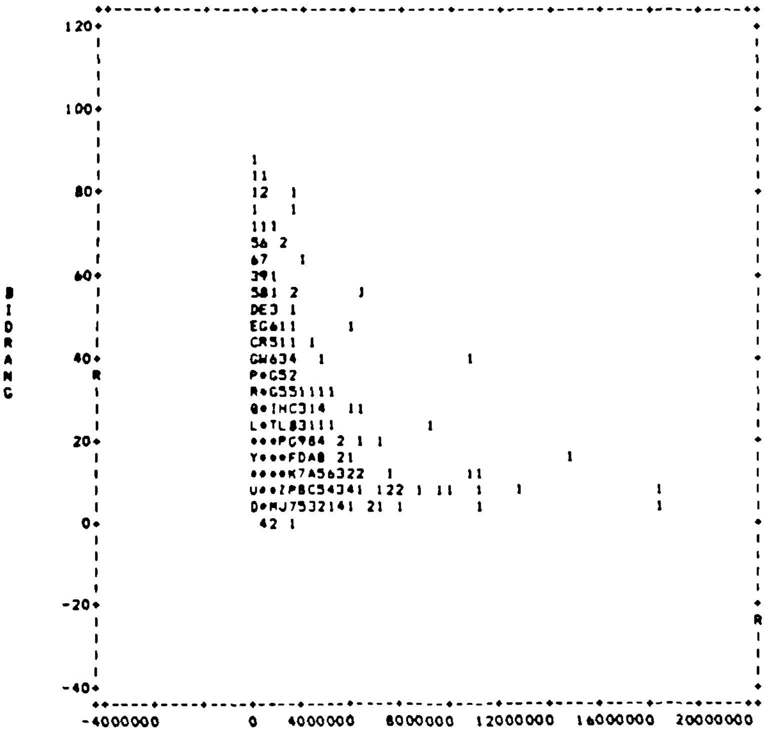
2261 cases plotted. Regression statistics of BIDRD on BID1:
Correlation -.22170 R Squared .04915 S.E. of Est 7.19465 Sig. .0000
Intercept(S.E.) 12.18257(.18831) Slope(S.E.) .00000(.00000)

PLOT OF BIDRANG WITH NOBID



2261 cases plotted. Regression statistics of BIDRANG on NOBID:
Correlation .06267 R Squared .00393 S.E. of Est 13.61187 Sig. .0029
Intercept(S.E.) 17.71487(1.01010) Slope(S.E.) .60195(.20168)

PLOT OF BIDRANG WITH BID1



2261 cases plotted. Regression statistics of BIDRANG on BID1:
Correlation -.17849 R Squared .03186 S.E. of Est 13.41966 Sig. .0000
Intercept(S.E.) 22.40891(.35124) Slope(S.E.) .00000(.00000)

APPENDIX F

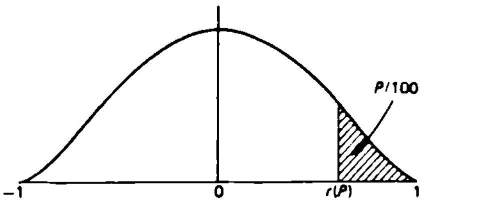
STATISTICAL TABLES

PERCENTAGE POINTS OF THE CORRELATION COEFFICIENT r WHEN $\rho = 0$

The function tabulated is $r(P) = r(P|\nu)$ defined by the equation

$$\frac{\Gamma\left(\frac{\nu-1}{2}\right)}{\sqrt{\pi}\,\Gamma\left(\frac{\nu-2}{2}\right)}\int_{r(P)}^{1}(1-r^2)^{\frac{\nu-4}{2}}\,dr = P/100.$$

Let r be a partial correlation coefficient, after s variables have been eliminated, in a sample of size n from a multivariate normal population with corresponding true partial correlation coefficient $\rho = 0$, and let $\nu = n - s$. This table gives upper P per cent points of r; the corresponding lower P per cent points are given by $-r(P)$, and the tabulated values are also upper $2P$ per cent points of $|r|$. For $s = 0$ we have $\nu = n$ and r is the ordinary correlation coefficient. When $\nu > 130$ use the results that r is approximately normally distributed with zero mean and variance $\frac{1}{\nu - 1}$, or (more accurately) that $z = \tanh^{-1} r$ is approximately normally distributed with zero mean and variance $\frac{1}{\nu - 3}$ (cf. Tables 16 and 17).



(This shape applies for $\nu \geq 5$ only. When $\nu = 4$ the distribution is uniform and when $\nu = 3$ the probability density function is U-shaped.)

Tables of the distribution of r for various values of ρ are given by, for example, F. N. David, *Tables of the Ordinates and Probability Integral of the Distribution of the Correlation Coefficient in Small Samples*, Cambridge University Press (1954), and R. E. Odeh, 'Critical values of the sample product–moment correlation coefficient in the bivariate normal distribution', *Commun. Statist. - Simula Computa.* 11 (1) (1982), pp. 1–26. The z-transformation may also be used (cf. Tables 16 and 17).

P	5	2·5	1	0·5	0·1
ν = 3	0·9877	0·9969	0·9995	0·9999	0·999995
4	·9000	·9500	·9800	9900	9980
5	0·8054	0·8783	0·9343	0·9587	0·9859
6	·7293	8114	8822	·9172	9633
7	6694	·7545	·8329	8745	·9350
8	·6215	·7067	7887	·8343	·9049
9	·5822	6664	·7498	·7977	·8751
10	0·5494	0·6319	0·7155	0·7646	0·8467
11	·5214	·6021	·6851	7348	8199
12	·4973	·5760	·6581	·7079	7950
13	·4762	·5529	·6339	·6835	·7717
14	·4575	5324	·6120	·6614	·7501
15	0·4409	0·5140	0·5923	0·6411	0·7301
16	·4259	·4973	5742	·6226	·7114
17	4124	·4821	·5577	·6055	·6940
18	·4000	·4683	5425	·5897	·6777
19	·3887	·4555	·5285	·5751	6624
20	0·3783	0·4438	0·5155	0·5614	0·6481
21	·3687	·4329	5034	·5487	6346
22	·3598	·4227	·4921	5368	6219
23	·3515	·4132	·4815	·5256	6099
24	·3438	·4044	4716	5151	5986
25	0·3365	0·3961	0·4622	0·5052	0·5879
26	·3297	3882	4534	4958	·5776
27	·3233	3809	4451	4869	5679
28	·3172	·3739	4372	4785	5587
29	·3115	·3673	·4297	·4705	5499
30	0·3061	0·3610	0·4226	0·4629	0·5415
31	·3009	·3550	4158	4556	5334
32	·2960	·3494	·4093	4487	·5257
33	·2913	·3440	·4032	·4421	·5184
34	·2869	·3388	·3972	·4357	5113
35	0·2826	0·3338	0·3916	0·4296	0·5045
36	·2785	·3291	·3862	4238	4979
37	·2746	·3246	·3810	·4182	·4916
38	·2709	·3202	·3760	·4128	·4856
39	·2673	·3160	·3712	·4076	·4797
ν = 40	0·2638	0·3120	0·3665	0·4026	0·4741
42	·2573	·3044	·3578	·3932	·4633
44	·2512	·2973	·3496	·3843	·4533
46	·2455	·2907	·3420	·3761	·4439
48	2403	·2845	·3348	·3683	4351
50	0·2353	0·2787	0·3281	0·3610	0·4267
52	·2306	·2732	·3218	·3542	4188
54	·2262	2681	·3158	·3477	·4114
56	·2221	·2632	·3102	3415	·4043
58	·2181	·2586	·3048	·3357	3976
60	0·2144	0·2542	0·2997	0·3301	0·3912
62	·2108	·2500	2948	·3248	3850
64	·2075	2461	2902	·3198	3792
66	·2042	·2423	·2858	·3150	3736
68	·2012	·2387	·2816	·3104	3683
70	0·1982	0·2352	0·2776	0·3060	0·3632
72	·1954	2319	·2737	·3017	3583
74	·1927	2287	2700	·2977	·3536
76	·1901	2257	·2664	2938	3490
78	1876	2227	2630	·2900	3447
80	0·1852	0·2199	0·2597	0·2864	0·3405
82	1829	2172	·2565	·2830	3364
84	1807	2146	2535	2796	3325
86	1786	2120	·2505	2764	3287
88	1765	2096	2477	2732	3251
90	0·1745	0·2072	0·2449	0·2702	0·3215
92	1726	·2050	·2422	2673	·3181
94	·1707	·2028	·2396	2645	3148
96	·1689	2006	·2371	·2617	3116
98	1671	·1986	·2347	·2591	·3085
100	0·1654	0·1966	0·2324	0·2565	0·3054
105	1614	·1918	·2268	·2504	·2983
110	·1576	1874	·2216	·2446	2915
115	·1541	·1832	·2167	·2393	·2853
120	·1509	·1793	·2122	·2343	·2794
125	0·1478	0·1757	0·2079	0·2296	0·2738
130	·1449	·1723	·2039	·2252	2686

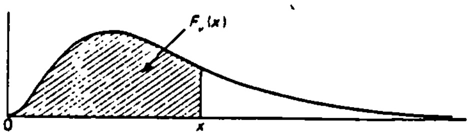
The function tabulated is

$$F_\nu(x) = \frac{1}{2^{\nu/2}\Gamma(\frac{\nu}{2})}\int_0^x t^{\frac{1}{2}\nu-1}e^{-\frac{1}{2}t}\,dt$$

for integer $\nu \leqslant 25$. $F_\nu(x)$ is the probability that a random variable X, distributed as χ^2 with ν degrees of freedom, will be less than or equal to x. Note that $F_1(x) = 2\Phi(x^{\frac{1}{2}}) - 1$ (cf. Table 4). For certain values of x and $\nu > 25$ use may be made of the following relation between the χ^2- and Poisson distributions:

$$F_\nu(x) = 1 - F(\tfrac{1}{2}\nu - 1 \mid \tfrac{1}{2}x)$$

where $F(r|\mu)$ is the Poisson distribution function (see Table 2). If $\nu > 25$, X is approximately normally distributed



(The above shape applies for $\nu \geqslant 3$ only. When $\nu < 3$ the mode is at the origin.)

with mean ν and variance 2ν. A better approximation is usually obtained by using the formula

$$F_\nu(x) \doteqdot \Phi(\sqrt{2x} - \sqrt{2\nu - 1})$$

where $\Phi(s)$ is the normal distribution function (see Table 4).

Omitted entries to the left and right of tabulated values are 1 and 0 respectively (to four decimal places).

$\nu =$	1	$\nu =$	1	$\nu =$	2	$\nu =$	2	$\nu =$	3	$\nu =$	3
x = 0·0	0·0000	x = 4·0	0·9545	x = 0·0	0·0000	x = 4·0	0·8647	x = 0·0	0·0000	x = 4·0	0·7385
·1	·2482	·1	·9571	·1	·0488	·1	·8713	·1	·0082	·2	·7593
·2	·3453	·2	·9596	·2	·0952	·2	·8775	·2	·0224	·4	·7786
·3	·4161	·3	·9619	·3	·1393	·3	·8835	·3	·0400	·6	·7965
·4	·4729	·4	·9641	·4	·1813	·4	·8892	·4	·0598	·8	·8130
0·5	0·5205	4·5	0·9661	0·5	0·2212	4·5	0·8946	0·5	0·0811	5·0	0·8282
·6	·5614	·6	·9680	·6	·2592	·6	·8997	·6	·1036	·2	·8423
·7	·5972	·7	·9698	·7	·2953	·7	·9046	·7	·1268	·4	·8553
·8	·6289	·8	·9715	·8	·3297	·8	·9093	·8	·1505	·6	·8672
·9	·6572	·9	·9731	·9	·3624	·9	·9137	·9	·1746	·8	·8782
1·0	0·6827	5·0	0·9747	1·0	0·3935	5·0	0·9179	1·0	0·1987	6·0	0·8884
·1	·7057	·1	·9761	·1	·4231	·1	·9219	·1	·2229	·2	·8977
·2	·7267	·2	·9774	·2	·4512	·2	·9257	·2	·2470	·4	·9063
·3	·7458	·3	·9787	·3	·4780	·3	·9293	·3	·2709	·6	·9142
·4	·7633	·4	·9799	·4	·5034	·4	·9328	·4	·2945	·8	·9214
1·5	0·7793	5·5	0·9810	1·5	0·5276	5·5	0·9361	1·5	0·3177	7·0	0·9281
·6	·7941	·6	·9820	·6	·5507	·6	·9392	·6	·3406	·2	·9342
·7	·8077	·7	·9830	·7	·5726	·7	·9422	·7	·3631	·4	·9398
·8	·8203	·8	·9840	·8	·5934	·8	·9450	·8	·3851	·6	·9450
·9	·8319	·9	·9849	·9	·6133	·9	·9477	·9	·4066	·8	·9497
2·0	0·8427	6·0	0·9857	2·0	0·6321	6·0	0·9502	2·0	0·4276	8·0	0·9540
·1	·8527	·1	·9865	·1	·6501	·2	·9550	·1	·4481	·2	·9579
·2	·8620	·2	·9872	·2	·6671	·4	·9592	·2	·4681	·4	·9616
·3	·8706	·3	·9879	·3	·6834	·6	·9631	·3	·4875	·6	·9649
·4	·8787	·4	·9886	·4	·6988	·8	·9666	·4	·5064	·8	·9679
2·5	0·8862	6·5	0·9892	2·5	0·7135	7·0	0·9698	2·5	0·5247	9·0	0·9707
·6	·8931	·6	·9898	·6	·7275	·2	·9727	·6	·5425	·2	·9733
·7	·8997	·7	·9904	·7	·7408	·4	·9753	·7	·5598	·4	·9756
·8	·9057	·8	·9909	·8	·7534	·6	·9776	·8	·5765	·6	·9777
·9	·9114	·9	·9914	·9	·7654	·8	·9798	·9	·5927	·8	·9797
3·0	0·9167	7·0	0·9918	3·0	0·7769	8·0	0·9817	3·0	0·6084	10·0	0·9814
·1	·9217	·1	·9923	·1	·7878	·2	·9834	·1	·6235	·2	·9831
·2	·9264	·2	·9927	·2	·7981	·4	·9850	·2	·6382	·4	·9845
·3	·9307	·3	·9931	·3	·8080	·6	·9864	·3	·6524	·6	·9859
·4	·9348	·4	·9935	·4	·8173	·8	·9877	·4	·6660	·8	·9871
3·5	0·9386	7·5	0·9938	3·5	0·8262	9·0	0·9889	3·5	0·6792	11·0	0·9883
·6	·9422	·6	·9942	·6	·8347	·2	·9899	·6	·6920	·2	·9893
·7	·9456	·7	·9945	·7	·8428	·4	·9909	·7	·7043	·4	·9903
·8	·9487	·8	·9948	·8	·8504	·6	·9918	·8	·7161	·6	·9911
·9	·9517	·9	·9951	·9	·8577	·8	·9926	·9	·7275	·8	·9919
4·0	0·9545	8·0	0·9953	4·0	0·8647	10·0	0·9933	4·0	0·7385	12·0	0·9926

THE χ^2-DISTRIBUTION FUNCTION

$\nu =$	4	5	6	7	8	9	10	11	12	13	14
$x =$ 0·5	0·0265	0·0079	0·0022	0·0006	0·0001						
1·0	·0902	·0374	·0144	·0052	·0018	0·0006	0·0002	0·0001			
1·5	·1734	·0869	·0405	·0177	·0073	·0029	·0011	·0004	0·0001		
2·0	·2642	·1509	·0803	·0402	·0190	·0085	·0037	·0015	·0006	0·0002	0·0001
2·5	0·3554	0·2235	0·1315	0·0729	0·0383	0·0191	0·0091	0·0042	0·0018	0·0008	0·0003
3·0	·4422	·3000	·1912	·1150	0656	·0357	·0186	·0093	·0045	·0021	·0009
3·5	·5221	·3766	·2560	·1648	·1008	·0589	·0329	·0177	·0091	·0046	·0022
4·0	·5940	·4506	·3233	·2202	·1429	·0886	·0527	·0301	·0166	·0088	·0045
4·5	·6575	5201	·3907	·2793	·1906	·1245	·0780	·0471	·0274	·0154	·0084
5·0	0·7127	0·5841	0·4562	0·3400	0·2424	0·1657	0·1088	0·0688	0·0420	0·0248	0·0142
5·5	·7603	·6421	·5185	·4008	·2970	·2113	·1446	·0954	·0608	·0375	·0224
6·0	·8009	·6938	·5768	·4603	·3528	·2601	·1847	·1266	·0839	·0538	·0335
6·5	·8352	·7394	·6304	·5173	·4086	·3110	·2283	·1620	·1112	·0739	·0477
7·0	·8641	·7794	·6792	·5711	·4634	·3629	·2746	·2009	·1424	·0978	·0653
7·5	0·8883	0·8140	0·7229	0·6213	0·5162	0·4148	0·3225	0·2427	0·1771	0·1254	0·0863
8·0	·9084	·8438	·7619	·6674	·5665	·4659	·3712	·2867	·2149	·1564	·1107
8·5	·9251	·8693	·7963	·7094	·6138	·5154	·4199	·3321	·2551	·1904	·1383
9·0	·9389	·8909	·8264	·7473	·6577	·5627	·4679	·3781	·2971	·2271	·1689
9·5	·9503	·9093	·8527	·7813	·6981	·6075	·5146	·4242	·3403	·2658	·2022
10·0	0·9596	0·9248	0·8753	0·8114	0·7350	0·6495	0·5595	0·4696	0·3840	0·3061	0·2378
10·5	·9672	9378	·8949	8380	·7683	·6885	·6022	·5140	·4278	·3474	·2752
11·0	·9734	·9486	·9116	·8614	·7983	·7243	·6425	·5567	·4711	·3892	·3140
11·5	·9785	9577	·9259	·8818	8251	·7570	·6801	·5976	·5134	·4310	·3536
12·0	·9826	·9652	·9380	·8994	·8488	·7867	·7149	·6364	·5543	·4724	·3937
12·5	0·9860	0·9715	0·9483	0·9147	0·8697	0·8134	0·7470	0·6727	0·5936	0·5129	0·4338
13·0	·9887	·9766	9570	·9279	8882	8374	·7763	·7067	·6310	·5522	·4735
13·5	9909	9809	9643	·9392	9042	8587	·8030	·7381	·6662	5900	·5124
14·0	9927	9844	9704	9488	·9182	8777	8270	·7670	·6993	6262	5503
14·5	·9941	9873	·9755	9570	·9304	·8944	8486	·7935	·7301	·6604	·5868
15·0	0·9953	0·9896	0·9797	0·9640	0·9409	0·9091	0·8679	0·8175	0·7586	0·6926	0·6218
15·5	·9962	·9916	9833	9699	9499	·9219	8851	8393	7848	·7228	·6551
16·0	9970	9932	9862	9749	9576	9331	9004	8589	8088	·7509	6866
16·5	9976	9944	9887	9791	9642	·9429	9138	8764	8306	7768	·7162
17·0	9981	9955	·9907	9826	9699	·9513	9256	8921	8504	8007	7438
17·5	0·9985	0·9964	0·9924	0·9856	0·9747	0·9586	0·9360	0·9061	0·8683	0·8226	0·7695
18·0	9988	9971	·9938	9880	9788	9648	9450	9184	8843	8425	7932
18·5	·9990	9976	·9949	9901	·9822	9702	9529	9293	8987	8606	·8151
19·0	·9992	·9981	9958	9918	·9851	·9748	·9597	·9389	·9115	8769	8351
19·5	·9994	·9984	·9966	9932	·9876	9787	9656	9473	·9228	8916	8533
20	0·9995	0·9988	0·9972	0·9944	0·9897	0·9821	0·9707	0·9547	0·9329	0·9048	0·8699
21	·9997	·9992	9982	·9962	9929	9873	9789	·9666	9496	9271	·8984
22	·9998	·9995	·9988	9975	·9951	9911	·9849	·9756	9625	9446	9214
23	·9999	·9997	·9992	9983	9966	9938	9893	9823	9723	·9583	·9397
24	·9999	·9998	·9995	9989	·9977	·9957	·9924	9873	9797	9689	·9542
25	0·9999	0·9999	0·9997	0·9992	0·9984	0·9970	0·9947	0·9909	0·9852	0·9769	0·9654
26		·9999	·9998	·9995	9989	9980	9963	9935	·9893	·9830	·9741
27		·9999	·9999	9997	9993	9986	9974	9954	9923	9876	9807
28			·9999	·9998	9995	9990	9982	9968	9945	9910	9858
29			·9999	·9999	9997	·9994	·9988	9977	9961	9935	9895
30				0·9999	0·9998	0·9996	0·9991	0·9984	0·9972	0·9953	0·9924

THE χ^2-DISTRIBUTION FUNCTION

$\nu =$	15	16	17	18	19	20	21	22	23	24	25
$x = 3$	0·0004	0·0002	0·0001								
4	·0023	·0011	·0005	0·0002	0·0001						
5	0·0079	0·0042	0·0022	0·0011	0·0006	0·0003	0·0001	0·0001			
6	·0203	·0119	·0068	·0038	·0021	·0011	·0005	·0003	0·0001	0·0001	
7	·0424	·0267	·0165	·0099	·0058	·0033	·0019	·0010	·0005	·0003	0·0001
8	·0762	·0511	·0335	·0214	·0133	·0081	·0049	·0028	·0016	·0009	·0005
9	·1225	·0866	·0597	·0403	·0265	·0171	·0108	·0067	·0040	·0024	·0014
10	0·1803	0·1334	0·0964	0·0681	0·0471	0·0318	0·0211	0·0137	0·0087	0·0055	0·0033
11	·2474	·1905	·1434	·1056	·0762	·0538	·0372	·0253	·0168	·0110	·0071
12	·3210	·2560	·1999	·1528	·1144	·0839	·0604	·0426	·0295	·0201	·0134
13	·3977	·3272	·2638	·2084	·1614	·1226	·0914	·0668	·0480	·0339	·0235
14	·4745	·4013	·3329	·2709	·2163	·1695	·1304	·0985	·0731	·0533	·0383
15	0·5486	0·4754	0·4045	0·3380	0·2774	0·2236	0·1770	0·1378	0·1054	0·0792	0·0586
16	·6179	·5470	·4762	·4075	·3427	·2834	·2303	·1841	·1447	·1119	·0852
17	·6811	·6144	·5456	·4769	·4101	·3470	·2859	·2366	·1907	·1513	·1182
18	·7373	·6761	·6112	·5443	·4776	·4126	·3510	·2940	·2425	·1970	·1576
19	·7863	·7313	·6715	·6082	·5432	·4782	·4149	·3547	·2988	·2480	·2029
20	0·8281	0·7798	0·7258	0·6672	0·6054	0·5421	0·4757	0·4170	0·3581	0·3032	0·2532
21	·8632	·8215	·7737	·7206	·6632	·6029	·5411	·4793	·4189	·3613	·3074
22	·8922	·8568	·8153	·7680	·7157	·6595	·6005	·5401	·4797	·4207	·3643
23	·9159	·8863	·8507	·8094	·7627	·7112	·6550	·5983	·5392	·4802	·4224
24	·9349	·9105	·8806	·8450	·8038	·7570	·7060	·6528	·5962	·5384	·4806
25	0·9501	0·9302	0·9053	0·8751	0·8395	0·7985	0·7528	0·7029	0·6497	0·5942	0·5376
26	·9620	·9460	·9255	·9002	·8698	·8342	·7936	·7483	·6991	·6468	·5924
27	·9713	·9585	·9419	·9210	·8953	·8647	·8201	·7888	·7440	·6955	·6441
28	·9784	·9684	·9551	·9379	·9166	·8906	·8598	·8243	·7842	·7400	·6921
29	·9839	·9761	·9655	·9516	·9340	·9122	·8860	·8551	·8197	·7799	·7361
30	0·9881	0·9820	0·9737	0·9626	0·9482	0·9301	0·9080	0·8815	0·8506	0·8152	0·7757
31	·9912	·9865	·9800	·9712	·9596	·9448	·9263	·9039	·8772	·8462	·8110
32	·9939	·9900	·9850	·9780	·9687	·9567	·9414	·9226	·8999	·8730	·8420
33	·9953	·9926	·9887	·9833	·9760	·9663	·9538	·9381	·9189	·8959	·8689
34	·9966	·9946	·9916	·9874	·9816	·9739	·9638	·9509	·9348	·9153	·8921
35	0·9975	0·9960	0·9938	0·9905	0·9860	0·9769	0·9718	0·9613	0·9480	0·9316	0·9118
36	·9982	·9971	·9954	·9929	·9894	·9840	·9791	·9696	·9587	·9451	·9284
37	·9987	·9979	·9966	·9948	·9921	·9883	·9832	·9763	·9675	·9562	·9423
38	·9991	·9985	·9975	·9961	·9941	·9911	·9871	·9817	·9745	·9653	·9537
39	·9994	·9989	·9982	·9972	·9956	·9933	·9902	·9859	·9802	·9727	·9632
40	0·9995	0·9992	0·9987	0·9979	0·9967	0·9950	0·9926	0·9892	0·9846	0·9786	0·9708
41	·9997	·9994	·9991	·9985	·9976	·9963	·9944	·9918	·9882	·9833	·9770
42	·9998	·9996	·9993	·9989	·9982	·9972	·9958	·9937	·9909	·9871	·9820
43	·9998	·9997	·9995	·9992	·9987	·9980	·9969	·9953	·9931	·9901	·9860
44	·9999	·9998	·9997	·9994	·9991	·9985	·9977	·9965	·9947	·9924	·9892
45	0·9999	0·9999	0·9998	0·9996	0·9993	0·9989	0·9983	0·9973	0·9960	0·9942	0·9916
46	·9999	·9999	·9998	·9997	·9995	·9992	·9987	·9980	·9970	·9956	·9936
47		·9999	·9999	·9998	·9996	·9994	·9991	·9985	·9978	·9967	·9951
48			·9999	·9998	·9997	·9996	·9993	·9989	·9983	·9975	·9963
49			·9999	·9999	·9998	·9997	·9995	·9992	·9988	·9981	·9972
50				0·9999	0·9999	0·9998	0·9996	0·9994	0·9991	0·9986	0·9979

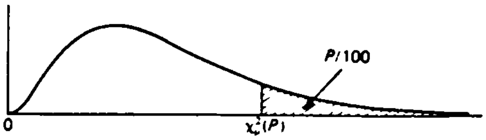
PERCENTAGE POINTS OF THE χ^2-DISTRIBUTION

This table gives percentage points $\chi^2_\nu(P)$ defined by the equation

$$\frac{P}{100} = \frac{1}{2^{\nu/2}\,\Gamma(\frac{\nu}{2})} \int_{\chi^2_\nu(P)}^{\infty} x^{\frac{1}{2}\nu-1} e^{-\frac{1}{2}x}\, dx.$$

If X is a variable distributed as χ^2 with ν degrees of freedom, $P/100$ is the probability that $X \geqslant \chi^2_\nu(P)$.

For $\nu > 100$, $\sqrt{2X}$ is approximately normally distributed with mean $\sqrt{2\nu-1}$ and unit variance.

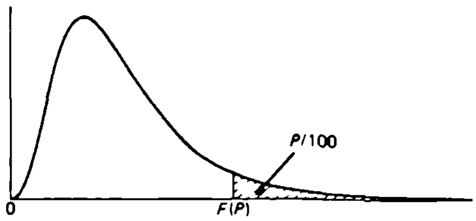


(The above shape applies for $\nu \geqslant 3$ only. When $\nu < 3$ the mode is at the origin.)

P	50	40	30	20	10	5	2.5	1	0.5	0.1	0.05
ν = 1	0.4549	0.7083	1.074	1.642	2.706	3.841	5.024	6.635	7.879	10.83	12.12
2	1.386	1.833	2.408	3.219	4.605	5.991	7.378	9.210	10.60	13.82	15.20
3	2.366	2.946	3.665	4.642	6.251	7.815	9.348	11.34	12.84	16.27	17.73
4	3.357	4.045	4.878	5.989	7.779	9.488	11.14	13.28	14.86	18.47	20.00
5	4.351	5.132	6.064	7.289	9.236	11.07	12.83	15.09	16.75	20.52	22.11
6	5.348	6.211	7.231	8.558	10.64	12.59	14.45	16.81	18.55	22.46	24.10
7	6.346	7.283	8.383	9.803	12.02	14.07	16.01	18.48	20.28	24.32	26.02
8	7.344	8.351	9.524	11.03	13.36	15.51	17.53	20.09	21.95	26.12	27.87
9	8.343	9.414	10.66	12.24	14.68	16.92	19.02	21.67	23.59	27.88	29.67
10	9.342	10.47	11.78	13.44	15.99	18.31	20.48	23.21	25.19	29.59	31.42
11	10.34	11.53	12.90	14.63	17.28	19.68	21.92	24.72	26.76	31.26	33.14
12	11.34	12.58	14.01	15.81	18.55	21.03	23.34	26.22	28.30	32.91	34.82
13	12.34	13.64	15.12	16.98	19.81	22.36	24.74	27.69	29.82	34.53	36.48
14	13.34	14.69	16.22	18.15	21.06	23.68	26.12	29.14	31.32	36.12	38.11
15	14.34	15.73	17.32	19.31	22.31	25.00	27.49	30.58	32.80	37.70	39.72
16	15.34	16.78	18.42	20.47	23.54	26.30	28.85	32.00	34.27	39.25	41.31
17	16.34	17.82	19.51	21.61	24.77	27.59	30.19	33.41	35.72	40.79	42.88
18	17.34	18.87	20.60	22.76	25.99	28.87	31.53	34.81	37.16	42.31	44.43
19	18.34	19.91	21.69	23.90	27.20	30.14	32.85	36.19	38.58	43.82	45.97
20	19.34	20.95	22.77	25.04	28.41	31.41	34.17	37.57	40.00	45.31	47.50
21	20.34	21.99	23.86	26.17	29.62	32.67	35.48	38.93	41.40	46.80	49.01
22	21.34	23.03	24.94	27.30	30.81	33.92	36.78	40.29	42.80	48.27	50.51
23	22.34	24.07	26.02	28.43	32.01	35.17	38.08	41.64	44.18	49.73	52.00
24	23.34	25.11	27.10	29.55	33.20	36.42	39.36	42.98	45.56	51.18	53.48
25	24.34	26.14	28.17	30.68	34.38	37.65	40.65	44.31	46.93	52.62	54.95
26	25.34	27.18	29.25	31.79	35.56	38.89	41.92	45.64	48.29	54.05	56.41
27	26.34	28.21	30.32	32.91	36.74	40.11	43.19	46.96	49.64	55.48	57.86
28	27.34	29.25	31.39	34.03	37.92	41.34	44.46	48.28	50.99	56.89	59.30
29	28.34	30.28	32.46	35.14	39.09	42.56	45.72	49.59	52.34	58.30	60.73
30	29.34	31.32	33.53	36.25	40.26	43.77	46.98	50.89	53.67	59.70	62.16
32	31.34	33.38	35.66	38.47	42.58	46.19	49.48	53.49	56.33	62.49	65.00
34	33.34	35.44	37.80	40.68	44.90	48.60	51.97	56.06	58.96	65.25	67.80
36	35.34	37.50	39.92	42.88	47.21	51.00	54.44	58.62	61.58	67.99	70.59
38	37.34	39.56	42.05	45.08	49.51	53.38	56.90	61.16	64.18	70.70	73.35
40	39.34	41.62	44.16	47.27	51.81	55.76	59.34	63.69	66.77	73.40	76.09
50	49.33	51.89	54.72	58.16	63.17	67.50	71.42	76.15	79.49	86.66	89.56
60	59.33	62.13	65.23	68.97	74.40	79.08	83.30	88.38	91.95	99.61	102.7
70	69.33	72.36	75.69	79.71	85.53	90.53	95.02	100.4	104.2	112.3	115.6
80	79.33	82.57	86.12	90.41	96.58	101.9	106.6	112.3	116.3	124.8	128.3
90	89.33	92.76	96.52	101.1	107.6	113.1	118.1	124.1	128.3	137.2	140.8
100	99.33	102.9	106.9	111.7	118.5	124.3	129.6	135.8	140.2	149.4	153.2

5 PER CENT POINTS OF THE F-DISTRIBUTION

If $F = \dfrac{X_1}{\nu_1}\Big/\dfrac{X_2}{\nu_2}$, where X_1 and X_2 are independent random variables distributed as χ^2 with ν_1 and ν_2 degrees of freedom respectively, then the probabilities that $F \geqslant F(P)$ and that $F \leqslant F'(P)$ are both equal to $P/100$. Linear interpolation in ν_1 and ν_2 will generally be sufficiently accurate except when either $\nu_1 > 12$ or $\nu_2 > 40$, when harmonic interpolation should be used.



(This shape applies only when $\nu_1 \geqslant 3$. When $\nu_1 < 3$ the mode is at the origin.)

$\nu_1 =$	1	2	3	4	5	6	7	8	10	12	24	∞
$\nu_2 =$ 1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	241.9	243.9	249.1	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.40	19.41	19.45	19.50
3	10.13	9.552	9.277	9.117	9.013	8.941	8.887	8.845	8.786	8.745	8.639	8.526
4	7.709	6.944	6.591	6.388	6.256	6.163	6.094	6.041	5.964	5.912	5.774	5.628
5	6.608	5.786	5.409	5.192	5.050	4.950	4.876	4.818	4.735	4.678	4.527	4.365
6	5.987	5.143	4.757	4.534	4.387	4.284	4.207	4.147	4.060	4.000	3.841	3.669
7	5.591	4.737	4.347	4.120	3.972	3.866	3.787	3.726	3.637	3.575	3.410	3.230
8	5.318	4.459	4.066	3.838	3.687	3.581	3.500	3.438	3.347	3.284	3.115	2.928
9	5.117	4.256	3.863	3.633	3.482	3.374	3.293	3.230	3.137	3.073	2.900	2.707
10	4.965	4.103	3.708	3.478	3.326	3.217	3.135	3.072	2.978	2.913	2.737	2.538
11	4.844	3.982	3.587	3.357	3.204	3.095	3.012	2.948	2.854	2.788	2.609	2.404
12	4.747	3.885	3.490	3.259	3.106	2.996	2.913	2.849	2.753	2.687	2.505	2.296
13	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.671	2.604	2.420	2.206
14	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.602	2.534	2.349	2.131
15	4.543	3.682	3.287	3.056	2.901	2.790	2.707	2.641	2.544	2.475	2.288	2.066
16	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.494	2.425	2.235	2.010
17	4.451	3.592	3.197	2.965	2.810	2.699	2.614	2.548	2.450	2.381	2.190	1.960
18	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.412	2.342	2.150	1.917
19	4.381	3.522	3.127	2.895	2.740	2.628	2.544	2.477	2.378	2.308	2.114	1.878
20	4.351	3.493	3.098	2.866	2.711	2.599	2.514	2.447	2.348	2.278	2.082	1.843
21	4.325	3.467	3.072	2.840	2.685	2.573	2.488	2.420	2.321	2.250	2.054	1.812
22	4.301	3.443	3.049	2.817	2.661	2.549	2.464	2.397	2.297	2.226	2.028	1.783
23	4.279	3.422	3.028	2.796	2.640	2.528	2.442	2.375	2.275	2.204	2.005	1.757
24	4.260	3.403	3.009	2.776	2.621	2.508	2.423	2.355	2.255	2.183	1.984	1.733
25	4.242	3.385	2.991	2.759	2.603	2.490	2.405	2.337	2.236	2.165	1.964	1.711
26	4.225	3.369	2.975	2.743	2.587	2.474	2.388	2.321	2.220	2.148	1.946	1.691
27	4.210	3.354	2.960	2.728	2.572	2.459	2.373	2.305	2.204	2.132	1.930	1.672
28	4.196	3.340	2.947	2.714	2.558	2.445	2.359	2.291	2.190	2.118	1.915	1.654
29	4.183	3.328	2.934	2.701	2.545	2.432	2.346	2.278	2.177	2.104	1.901	1.638
30	4.171	3.316	2.922	2.690	2.534	2.421	2.334	2.266	2.165	2.092	1.887	1.622
32	4.149	3.295	2.901	2.668	2.512	2.399	2.313	2.244	2.142	2.070	1.864	1.594
34	4.130	3.276	2.883	2.650	2.494	2.380	2.294	2.225	2.123	2.050	1.843	1.569
36	4.113	3.259	2.866	2.634	2.477	2.364	2.277	2.209	2.106	2.033	1.824	1.547
38	4.098	3.245	2.852	2.619	2.463	2.349	2.262	2.194	2.091	2.017	1.808	1.527
40	4.085	3.232	2.839	2.606	2.449	2.336	2.249	2.180	2.077	2.003	1.793	1.509
60	4.001	3.150	2.758	2.525	2.368	2.254	2.167	2.097	1.993	1.917	1.700	1.389
120	3.920	3.072	2.680	2.447	2.290	2.175	2.087	2.016	1.910	1.834	1.608	1.254
∞	3.841	2.996	2.605	2.372	2.214	2.099	2.010	1.938	1.831	1.752	1.517	1.000

CONFIDENCE LIMITS FOR A BINOMIAL PARAMETER

Suppose that we have obtained an observation, r, from a binomial distribution with index n and unknown parameter p. The following Table gives Bayesian confidence limits for p, assuming an improper prior density proportional to $[p(1-p)]^{-1/2}$. The median and the lower and upper quartiles of the posterior distribution of p are also given. When n > 50, one may use the approximate formula

$$\hat{p} \pm x(P)\sqrt{\frac{\hat{p}\,(1-\hat{p})}{n}}$$

where $\hat{p} = \frac{r}{n}$ and x(P) is the upper $P = \frac{1}{2}$ (100–C) point of the standard normal distribution (see Table 5), C being the confidence level per cent.

	CONFIDENCE LEVEL PER CENT										
	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$n=2$											
$r=0$	0.0009	0.5693	0.0002	0.6668	0.0000	0.8200	0.0000	0.9271	0.0222	0.0955	0.2529
1	0.0973	0.9027	0.0608	0.9392	0.0206	0.9794	0.0044	0.9956	0.2980	0.5000	0.7020
2	0.4307	0.9991	0.3332	0.9998	0.1800	1.0000	0.0729	1.0000	0.7471	0.9045	0.9778
$n=3$											
$r=0$	0.0006	0.4441	0.0002	0.5356	0.0000	0.6987	0.0000	0.8409	0.0155	0.0674	0.1835
1	0.0624	0.7645	0.0387	0.8233	0.0130	0.9084	0.0028	0.9638	0.1994	0.3525	0.5306
2	0.2355	0.9376	0.1767	0.9613	0.0916	0.9870	0.0362	0.9972	0.4694	0.6475	0.8006
3	0.5559	0.9994	0.4644	0.9998	0.3013	1.0000	0.1591	1.0000	0.8165	0.9326	0.9845
$n=4$											
$r=0$	0.0005	0.3625	0.0001	0.4448	0.0000	0.6020	0.0000	0.7567	0.0119	0.0520	0.1438
1	0.0460	0.6507	0.0285	0.7162	0.0096	0.8234	0.0020	0.9095	0.1499	0.2718	0.4239
2	0.1653	0.8347	0.1228	0.8772	0.0627	0.9373	0.0246	0.9754	0.3455	0.5000	0.6545
3	0.3493	0.9540	0.2338	0.9715	0.1766	0.9904	0.0905	0.9980	0.5761	0.7282	0.8501
4	0.6375	0.9995	0.5552	0.9999	0.3980	1.0000	0.2433	1.0000	0.8562	0.9480	0.9881
$n=5$											
$r=0$	0.0004	0.3057	0.0001	0.3794	0.0000	0.5264	0.0000	0.6826	0.0096	0.0423	0.1182
1	0.0364	0.5628	0.0225	0.6286	0.0075	0.7440	0.0016	0.8483	0.1201	0.2211	0.3523
2	0.1275	0.7394	0.0944	0.7906	0.0479	0.8718	0.0187	0.9351	0.2739	0.4068	0.5500
3	0.2606	0.8722	0.2094	0.9056	0.1282	0.9521	0.0649	0.9813	0.4500	0.5932	0.7261
4	0.4372	0.9636	0.3714	0.9775	0.2560	0.9925	0.1517	0.9984	0.6477	0.7789	0.8799
5	0.6943	0.9996	0.6206	0.9999	0.4736	1.0000	0.3174	1.0000	0.8818	0.9577	0.9904
$n=6$											
$r=0$	0.0003	0.2642	0.0001	0.3304	0.0000	0.4666	0.0000	0.6192	0.0081	0.0357	0.1003
1	0.0302	0.4945	0.0186	0.5581	0.0062	0.6746	0.0013	0.7883	0.1003	0.1863	0.3011
2	0.1043	0.6592	0.0768	0.7136	0.0388	0.8058	0.0151	0.8865	0.2271	0.3429	0.4732
3	0.2089	0.7911	0.1668	0.8332	0.1012	0.8988	0.0509	0.9491	0.3702	0.5000	0.6298
4	0.3408	0.8957	0.2864	0.9232	0.1942	0.9612	0.1135	0.9849	0.5268	0.6571	0.7729
5	0.5055	0.9698	0.4419	0.9814	0.3254	0.9938	0.2117	0.9987	0.6989	0.8137	0.8997
6	0.7358	0.9997	0.6696	0.9999	0.5334	1.0000	0.3808	1.0000	0.8997	0.9643	0.9919
$n=7$											
$r=0$	0.0003	0.2325	0.0001	0.2924	0.0000	0.4186	0.0000	0.5653	0.0070	0.0309	0.0872
1	0.0258	0.4404	0.0159	0.5008	0.0053	0.6151	0.0011	0.7329	0.0860	0.1610	0.2628
2	0.0881	0.5929	0.0647	0.6477	0.0326	0.7448	0.0126	0.8364	0.1940	0.2962	0.4149
3	0.1746	0.7192	0.1389	0.7655	0.0837	0.8426	0.0419	0.9088	0.3148	0.4320	0.5548
4	0.2808	0.8254	0.2345	0.8611	0.1574	0.9163	0.0912	0.9581	0.4452	0.5680	0.6852
5	0.4071	0.9119	0.3523	0.9353	0.2552	0.9674	0.1636	0.9874	0.5851	0.7038	0.8060
6	0.5596	0.9742	0.4992	0.9841	0.3849	0.9947	0.2671	0.9989	0.7372	0.8390	0.9140
7	0.7675	0.9997	0.7076	0.9999	0.5814	1.0000	0.4347	1.0000	0.9128	0.9691	0.9930
$n=8$											
$r=0$	0.0002	0.2075	0.0001	0.2622	0.0000	0.3792	0.0000	0.5193	0.0061	0.0272	0.0770
1	0.0225	0.3967	0.0138	0.4537	0.0046	0.5643	0.0010	0.6828	0.0753	0.1417	0.2332
2	0.0763	0.5378	0.0560	0.5916	0.0281	0.6901	0.0109	0.7880	0.1693	0.2608	0.3692
3	0.1501	0.6572	0.1190	0.7052	0.0715	0.7887	0.0357	0.8657	0.2739	0.3803	0.4952
4	0.2393	0.7607	0.1990	0.8010	0.1326	0.8674	0.0765	0.9235	0.3860	0.5000	0.6140
5	0.3428	0.8499	0.2948	0.8810	0.2113	0.9285	0.1343	0.9643	0.5048	0.6197	0.7261
6	0.4622	0.9237	0.4034	0.9440	0.3099	0.9719	0.2120	0.9891	0.6308	0.7392	0.8307
7	0.6033	0.9775	0.5463	0.9862	0.4357	0.9954	0.3172	0.9990	0.7668	0.8583	0.9247
8	0.7925	0.9998	0.7378	0.9999	0.6208	1.0000	0.4807	1.0000	0.9230	0.9728	0.9939

CONFIDENCE LEVEL PER CENT

$n = 9$

r	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0002	0.1874	0.0001	0.2376	0.0000	0.3465	0.0000	0.4799	0.0055	0.0243	0.0690
1	0.0199	0.3607	0.0123	0.4145	0.0041	0.5207	0.0009	0.6381	0.0670	0.1266	0.2095
2	0.0673	0.4916	0.0493	0.5438	0.0247	0.6417	0.0096	0.7428	0.1503	0.2329	0.3324
3	0.1317	0.6040	0.1042	0.6522	0.0624	0.7388	0.0311	0.8229	0.2425	0.3396	0.4470
4	0.2087	0.7032	0.1730	0.7459	0.1147	0.8192	0.0659	0.8858	0.3408	0.4465	0.5557
5	0.2968	0.7913	0.2541	0.8270	0.1808	0.8853	0.1142	0.9341	0.4443	0.5535	0.6592
6	0.3960	0.8683	0.3478	0.8958	0.2612	0.9376	0.1771	0.9689	0.5530	0.6604	0.7575
7	0.5084	0.9327	0.4562	0.9507	0.3583	0.9753	0.2572	0.9904	0.6676	0.7671	0.8497
8	0.6393	0.9801	0.5855	0.9877	0.4793	0.9959	0.3619	0.9991	0.7905	0.8734	0.9330
9	0.8126	0.9998	0.7624	0.9999	0.6535	1.0000	0.5201	1.0000	0.9310	0.9757	0.9945

$n = 10$

r	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0002	0.1708	0.0000	0.2172	0.0000	0.3188	0.0000	0.4457	0.0049	0.0219	0.0625
1	0.0179	0.3306	0.0110	0.3813	0.0037	0.4830	0.0008	0.5981	0.0603	0.1143	0.1901
2	0.0602	0.4525	0.0441	0.5028	0.0221	0.5988	0.0085	0.7011	0.1351	0.2104	0.3023
3	0.1173	0.5581	0.0927	0.6058	0.0553	0.6934	0.0275	0.7819	0.2176	0.3068	0.4072
4	0.1851	0.6527	0.1531	0.6963	0.1011	0.7736	0.0579	0.8475	0.3052	0.4034	0.5071
5	0.2619	0.7381	0.2235	0.7765	0.1582	0.8418	0.0995	0.9005	0.3971	0.5000	0.6029
6	0.3473	0.8149	0.3037	0.8469	0.2264	0.8989	0.1525	0.9421	0.4929	0.5966	0.6948
7	0.4419	0.8827	0.3942	0.9073	0.3066	0.9447	0.2181	0.9725	0.5928	0.6932	0.7824
8	0.5475	0.9398	0.4972	0.9559	0.4012	0.9779	0.2989	0.9915	0.6977	0.7896	0.8649
9	0.6694	0.9821	0.6187	0.9890	0.5170	0.9963	0.4019	0.9992	0.8099	0.8857	0.9397
10	0.8292	0.9998	0.7828	1.0000	0.6812	1.0000	0.5543	1.0000	0.9375	0.9781	0.9951

$n = 11$

r	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
0	0.0002	0.1569	0.0000	0.2000	0.0000	0.2952	0.0000	0.4160	0.0045	0.0200	0.0571
1	0.0162	0.3050	0.0100	0.3530	0.0033	0.4501	0.0007	0.5623	0.0549	0.1043	0.1741
2	0.0545	0.4190	0.0398	0.4672	0.0199	0.5608	0.0077	0.6630	0.1226	0.1918	0.2771
3	0.1058	0.5184	0.0835	0.5651	0.0497	0.6525	0.0247	0.7434	0.1973	0.2798	0.3738
4	0.1664	0.6082	0.1373	0.6520	0.0905	0.7313	0.0517	0.8101	0.2764	0.3678	0.4662
5	0.2345	0.6903	0.1997	0.7301	0.1408	0.7999	0.0882	0.8659	0.3591	0.4559	0.5551
6	0.3097	0.7655	0.2699	0.8003	0.2001	0.8592	0.1341	0.9118	0.4449	0.5441	0.6409
7	0.3918	0.8336	0.3480	0.8627	0.2687	0.9095	0.1899	0.9483	0.5338	0.6322	0.7236
8	0.4816	0.8942	0.4349	0.9165	0.3475	0.9503	0.2566	0.9753	0.6262	0.7202	0.8027
9	0.5810	0.9455	0.5328	0.9602	0.4392	0.9801	0.3370	0.9923	0.7229	0.8082	0.8774
10	0.6950	0.9838	0.6470	0.9900	0.5499	0.9967	0.4377	0.9993	0.8259	0.8957	0.9451
11	0.8431	0.9998	0.8000	1.0000	0.7048	1.0000	0.5840	1.0000	0.9429	0.9800	0.9955

$n = 12$

r	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0002	[illegible]	0.0000	0.1853	0.0000	0.2748	0.0000	0.3898	0.0041	0.0184	0.0526
1	0.0149	0.2831	0.0091	0.3285	0.0030	0.4213	0.0007	0.5303	0.0503	0.0958	0.1605
2	0.0497	0.3900	0.0363	0.4362	0.0182	0.5271	0.0070	0.6283	0.1123	0.1763	0.2558
3	0.0964	0.4838	0.0759	0.5292	0.0452	0.6155	0.0224	0.7076	0.1805	0.2571	0.3454
4	0.1511	0.5691	0.1245	0.6124	0.0818	0.6925	0.0467	0.7745	0.2526	0.3380	0.4313
5	0.2124	0.6477	0.1805	0.6881	0.1268	0.7605	0.0793	0.8316	0.3278	0.4190	0.5142
6	0.2796	0.7204	0.2430	0.7570	0.1794	0.8206	0.1198	0.8802	0.4055	0.5000	0.5945
7	0.3523	0.7876	0.3119	0.8195	0.2395	0.8732	0.1684	0.9207	0.4858	0.5810	0.6722
8	0.4309	0.8489	0.3876	0.8755	0.3075	0.9182	0.2255	0.9533	0.5687	0.6620	0.7474
9	0.5162	0.9036	0.4708	0.9241	0.3845	0.9548	0.2924	0.9776	0.6546	0.7429	0.8195
10	0.6100	0.9503	0.5638	0.9637	0.4729	0.9818	0.3717	0.9930	0.7442	0.8237	0.8877
11	0.7169	0.9851	0.6715	0.9909	0.5787	0.9970	0.4697	0.9993	0.8395	0.9042	0.9497
12	0.8549	0.9998	0.8147	1.0000	0.7252	1.0000	0.6102	1.0000	0.9474	0.9816	0.9959

$n = 13$

r	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0001	0.1349	0.0000	0.1726	0.0000	0.2571	0.0000	0.3667	0.0038	0.0170	0.0487
1	0.0137	0.2641	0.0084	0.3071	0.0028	0.3959	0.0006	0.5016	0.0465	0.0886	0.1489
2	0.0458	0.3646	0.0334	0.4090	0.0167	0.4969	0.0064	0.5966	0.1036	0.1631	0.2375
3	0.0885	0.4533	0.0697	0.4974	0.0414	0.5821	0.0205	0.6744	0.1664	0.2379	0.3210
4	0.1385	0.5344	0.1139	0.5770	0.0747	0.6569	0.0426	0.7408	0.2326	0.3127	0.4012
5	0.1942	0.6095	0.1647	0.6500	0.1154	0.7238	0.0720	0.7985	0.3015	0.3876	0.4788
6	0.2549	0.6797	0.2211	0.7171	0.1627	0.7837	0.1083	0.8486	0.3727	0.4625	0.5541
7	0.3203	0.7451	0.2829	0.7789	0.2163	0.8373	0.1514	0.8917	0.4459	0.5375	0.6273
8	0.3905	0.8058	0.3500	0.8353	0.2762	0.8846	0.2015	0.9280	0.5212	0.6124	0.6985
9	0.4656	0.8615	0.4230	0.8861	0.3431	0.9253	0.2592	0.9574	0.5988	0.6873	0.7674
10	0.5467	0.9115	0.5026	0.9303	0.4179	0.9586	0.3256	0.9795	0.6790	0.7621	0.8336
11	0.6354	0.9542	0.5910	0.9666	0.5031	0.9833	0.4034	0.9936	0.7625	0.8369	0.8964
12	0.7359	0.9863	0.6929	0.9916	0.6041	0.9972	0.4984	0.9994	0.8511	0.9114	0.9535
13	0.8651	0.9999	0.8274	1.0000	0.7429	1.0000	0.6333	1.0000	0.9513	0.9830	0.9962

CONFIDENCE LEVEL PER CENT

$n = 14$	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0001	0.1261	0.0000	0.1616	0.0000	0.2414	0.0000	0.3461	0.0036	0.0158	0.0454
1	0.0127	0.2475	0.0078	0.2884	0.0026	0.3733	0.0006	0.4756	0.0431	0.0825	0.1388
2	0.0424	0.3424	0.0309	0.3849	0.0154	0.4699	0.0060	0.5676	0.0962	0.1517	0.2217
3	0.0818	0.4264	0.0643	0.4690	0.0382	0.5519	0.0189	0.6437	0.1543	0.2213	0.2999
4	0.1277	0.5035	0.1050	0.5453	0.0688	0.6245	0.0391	0.7093	0.2156	0.2909	0.3750
5	0.1789	0.5753	0.1515	0.6155	0.1059	0.6898	0.0659	0.7669	0.2792	0.3606	0.4478
6	0.2343	0.6428	0.2029	0.6806	0.1489	0.7490	0.0989	0.8177	0.3448	0.4303	0.5187
7	0.2938	0.7062	0.2589	0.7411	0.1972	0.8028	0.1377	0.8623	0.4122	0.5000	0.5878
8	0.3572	0.7657	0.3194	0.7971	0.2510	0.8511	0.1823	0.9011	0.4813	0.5697	0.6552
9	0.4247	0.8211	0.3845	0.8485	0.3102	0.8941	0.2331	0.9341	0.5522	0.6394	0.7208
10	0.4965	0.8723	0.4547	0.8950	0.3755	0.9312	0.2907	0.9609	0.6250	0.7091	0.7844
11	0.5736	0.9182	0.5310	0.9357	0.4481	0.9618	0.3563	0.9811	0.7001	0.7787	0.8457
12	0.6576	0.9576	0.6151	0.9691	0.5301	0.9846	0.4324	0.9940	0.7783	0.8483	0.9038
13	0.7525	0.9873	0.7116	0.9922	0.6267	0.9974	0.5244	0.9994	0.8612	0.9175	0.9569
14	0.8739	0.9999	0.8384	1.0000	0.7586	1.0000	0.6539	1.0000	0.9546	0.9842	0.9964

$n = 15$	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0001	0.1183	0.0000	0.1518	0.0000	0.2276	0.0000	0.3276	0.0033	0.0148	0.0425
1	0.0119	0.2328	0.0073	0.2718	0.0024	0.3531	0.0005	0.4521	0.0403	0.0771	0.1301
2	0.0394	0.3226	0.0288	0.3634	0.0144	0.4456	0.0055	0.5412	0.0897	0.1418	0.2078
3	0.0760	0.4024	0.0598	0.4436	0.0354	0.5245	0.0175	0.6153	0.1438	0.2068	0.2813
4	0.1186	0.4759	0.0974	0.5166	0.0637	0.5947	0.0362	0.6798	0.2008	0.2720	0.3520
5	0.1658	0.5446	0.1403	0.5842	0.0979	0.6584	0.0608	0.7369	0.2599	0.3371	0.4206
6	0.2169	0.6094	0.1875	0.6472	0.1373	0.7166	0.0910	0.7879	0.3208	0.4023	0.4875
7	0.2714	0.6706	0.2388	0.7061	0.1814	0.7699	0.1262	0.8334	0.3832	0.4674	0.5529
8	0.3294	0.7286	0.2939	0.7612	0.2301	0.8186	0.1666	0.8738	0.4471	0.5326	0.6168
9	0.3906	0.7831	0.3528	0.8125	0.2834	0.8627	0.2121	0.9090	0.5125	0.5977	0.6792
10	0.4554	0.8342	0.4158	0.8597	0.3416	0.9021	0.2631	0.9392	0.5794	0.6629	0.7401
11	0.5241	0.8814	0.4834	0.9026	0.4053	0.9363	0.3202	0.9638	0.6480	0.7280	0.7992
12	0.5976	0.9240	0.5564	0.9402	0.4755	0.9646	0.3847	0.9825	0.7187	0.7932	0.8562
13	0.6774	0.9606	0.6366	0.9712	0.5544	0.9856	0.4588	0.9945	0.7922	0.8582	0.9103
14	0.7672	0.9881	0.7282	0.9927	0.6469	0.9976	0.5479	0.9995	0.8699	0.9229	0.9597
15	0.8817	0.9999	0.8482	1.0000	0.7724	1.0000	0.6724	1.0000	0.9575	0.9852	0.9967

$n = 16$	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0001	0.1115	0.0000	0.1432	0.0000	0.2152	0.0000	0.3110	0.0031	0.0139	0.0399
1	0.0111	0.2198	0.0068	0.2569	0.0023	0.3349	0.0005	0.4307	0.0378	0.0724	0.1223
2	0.0369	0.3050	0.0269	0.3442	0.0134	0.4236	0.0052	0.5169	0.0841	0.1331	0.1956
3	0.0710	0.3809	0.0558	0.4208	0.0331	0.4995	0.0163	0.5891	0.1347	0.1942	0.2648
4	0.1107	0.4510	0.0908	0.4907	0.0593	0.5675	0.0337	0.6523	0.1880	0.2553	0.3316
5	0.1545	0.5168	0.1306	0.5557	0.0910	0.6294	0.0565	0.7087	0.2432	0.3165	0.3965
6	0.2018	0.5791	0.1743	0.6166	0.1273	0.6864	0.0842	0.7595	0.3000	0.3776	0.4598
7	0.2523	0.6382	0.2216	0.6739	0.1679	0.7390	0.1164	0.8053	0.3581	0.4388	0.5217
8	0.3056	0.6944	0.2722	0.7278	0.2125	0.7875	0.1534	0.8466	0.4176	0.5000	0.5824
9	0.3618	0.7477	0.3261	0.7784	0.2610	0.8321	0.1947	0.8834	0.4783	0.5612	0.6419
10	0.4209	0.7982	0.3834	0.8257	0.3136	0.8727	0.2405	0.9158	0.5402	0.6224	0.7000
11	0.4832	0.8455	0.4443	0.8694	0.3706	0.9090	0.2913	0.9435	0.6035	0.6835	0.7568
12	0.5490	0.8893	0.5093	0.9092	0.4325	0.9407	0.3477	0.9663	0.6684	0.7447	0.8120
13	0.6191	0.9290	0.5792	0.9442	0.5005	0.9669	0.4109	0.9837	0.7352	0.8058	0.8653
14	0.6950	0.9631	0.6558	0.9731	0.5764	0.9866	0.4831	0.9948	0.8044	0.8669	0.9159
15	0.7802	0.9889	0.7431	0.9932	0.6651	0.9977	0.5693	0.9995	0.8777	0.9276	0.9622
16	0.8885	0.9999	0.8568	1.0000	0.7848	1.0000	0.6890	1.0000	0.9601	0.9861	0.9969

$n = 17$	90		95		99		99.9		LOWER QUARTILE	MEDIAN	UPPER QUARTILE
$r = 0$	0.0001	0.1053	0.0000	0.1355	0.0000	0.2041	0.0000	0.2960	0.0029	0.0131	0.0376
1	0.0104	0.2082	0.0064	0.2436	0.0021	0.3185	0.0005	0.4112	0.0356	0.0682	0.1155
2	0.0347	0.2892	0.0253	0.3268	0.0126	0.4036	0.0049	0.4947	0.0791	0.1255	0.1847
3	0.0666	0.3616	0.0523	0.4001	0.0310	0.4768	0.0153	0.5649	0.1267	0.1830	0.2502
4	0.1037	0.4286	0.0851	0.4672	0.0555	0.5425	0.0315	0.6266	0.1767	0.2406	0.3134
5	0.1447	0.4916	0.1222	0.5298	0.0850	0.6026	0.0527	0.6822	0.2285	0.2982	0.3749
6	0.1888	0.5515	0.1629	0.5886	0.1188	0.6583	0.0784	0.7325	0.2817	0.3559	0.4350
7	0.2357	0.6085	0.2068	0.6441	0.1563	0.7100	0.1083	0.7783	0.3362	0.4135	0.4939
8	0.2852	0.6629	0.2536	0.6967	0.1974	0.7580	0.1422	0.8200	0.3917	0.4712	0.5516
9	0.3371	0.7148	0.3033	0.7464	0.2420	0.8026	0.1800	0.8578	0.4484	0.5288	0.6083
10	0.3915	0.7643	0.3559	0.7932	0.2900	0.8437	0.2217	0.8917	0.5061	0.5865	0.6638
11	0.4485	0.8112	0.4114	0.8371	0.3417	0.8812	0.2675	0.9216	0.5650	0.6441	0.7183
12	0.5084	0.8553	0.4702	0.8778	0.3974	0.9150	0.3178	0.9473	0.6251	0.7018	0.7715
13	0.5714	0.8963	0.5328	0.9149	0.4575	0.9445	0.3734	0.9685	0.6866	0.7594	0.8233
14	0.6384	0.9334	0.5999	0.9477	0.5232	0.9690	0.4351	0.9847	0.7498	0.8170	0.8733
15	0.7108	0.9653	0.6732	0.9747	0.5964	0.9874	0.5053	0.9951	0.8153	0.8745	0.9209
16	0.7918	0.9896	0.7564	0.9936	0.6815	0.9979	0.5888	0.9995	0.8845	0.9318	0.9644
17	0.8947	0.9999	0.8645	1.0000	0.7959	1.0000	0.7040	1.0000	0.9624	0.9869	0.9971

APPENDIX G

FORTRAN PROGRAM FOR COMPUTATION OF K VALUES FOR NORMAL AND EDGEWORTH DISTRIBUTION (DR W. F. SCOTT)

```
      REAL W(800)
      INTEGER IW(102)
      DIMENSION X(3), F(3)
        COMMON N,G1,G2
       EXTERNAL FST
       EPSABS=1.0E-6
       EPSREL=1.0E-6
       N=3
       PROB=0.5
       G1=0.076
       G2=0.016
       X(1)=-3.0
       X(2)=+3.0
       DO 100 J=1,50
       E=ABS(X(1)-X(2))
       IF (E.LT.1.0E-6) GOTO 200
       X(3)=0.5*(X(1)+X(2))
       DO 50 I=1,3
       IFAIL=0
       A=-10.0
       B=X(I)
       CALL D01AJE(FST,A,B,EPSABS,EPSREL,RESULT,ABSERR,W,
     *800,IW,102,IFAIL)
       F(I)=1.0-RESULT-PROB
50     CONTINUE
       IF (F(1)*F(3).GT.0) X(1)=X(3)
       IF (F(2)*F(3).GT.0) X(2)=X(3)
100    CONTINUE
200    WRITE(6,300) PROB, N, X(3)
300    FORMAT(1X,F10.5,I6,F10.5)
       STOP
       END

      REAL FUNCTION FST(X)
      REAL X
        COMMON N,G1,G2
       IFAIM=0
       FF=S15ABE(X,IFAIM)
      AA=0.3989422804
      F=AA*EXP(-0.5*X*X)
       AAA=(X*X-1)*G1/6.0
       AAA1=(X*X*X-3.0*X)*G2/24.0
       AAA2=(X**5-10.0*X*X*X+15.0*X)*G1*G1/72.0
       FF=FF-F*(AAA+AAA1+AAA2)
       BBB=1+(X*X*X-3.0*X)*G1/6
       BBB=BBB+(X**4-6.0*X*X+3)*G2/24.0
       BBB=BBB+(X**6-15.0*X**4+45.0*X*X-15.0)*G1*G1/72.0
       F=F*BBB
      FST=N*(1-FF)**(N-1)
      FST=FST*F
      RETURN
     END
```

APPENDIX H

DERIVATION OF AN UNBIASED ESTIMATOR (R) FOR RECIPROCAL OF TRUE COEFFICIENT OF VARIATION (DR W. F. SCOTT)

We use the notation as adopted by Cramer (1, page 382)

$$X = \left(\frac{n}{n-1}\right)s^2$$

has density

$$(n-1)k_{n-1}((n-1)x)$$

so,

$$X^{\frac{-1}{2}} = \left(\frac{1}{s\sqrt{\frac{n}{n-1}}}\right)$$

has mean

$$\int_0^\infty x^{\frac{-1}{2}} \frac{(n-1)(n-1)^{(\frac{n-1}{2}-1)} x^{(\frac{n-1}{2})-1} e^{-(n-1)\frac{x}{2}}}{2^{\frac{n-1}{2}}\Gamma(\frac{n-1}{2})} dx$$

Now let

$$y = (n-1)x$$

, so

$$dy = (n-1)dx$$

$$= \int_0^\infty \frac{y^{\frac{-1}{2}}(n-1)^{(\frac{n-1}{2}-1)}}{(n-1)^{\frac{-1}{2}}2^{\frac{n-1}{2}}\Gamma(\frac{n-1}{2})} \frac{y^{\frac{n-1}{2}-1}e^{\frac{-y}{2}}}{(n-1)^{(\frac{n-1}{2}-1)}} dy$$

$$= \sqrt{n-1}\int_0^\infty \frac{y^{\frac{n-2}{2}-1}e^{\frac{-y}{2}}}{2^{\frac{n-1}{2}}\Gamma(\frac{n-1}{2})} dy$$

$$= \frac{\sqrt{n-1}\,2^{\frac{n-2}{2}}\Gamma(\frac{n-2}{2})}{2^{\frac{n-1}{2}}\Gamma(\frac{n-1}{2})}$$

$$= \sqrt{\frac{n-1}{2}} * \frac{\Gamma(\frac{n-2}{2})}{\Gamma(\frac{n-1}{2})}$$

Now,

$$E\left(\frac{\bar{x}-\mu}{s}\right) = 0 \qquad \text{(using "t")}$$

So,

$$E\left(\frac{\bar{x}}{s}\right) = \frac{\mu}{\sigma}E\left(\frac{1}{s}\right) \qquad \text{(with s having } \sigma = 1\text{)}$$

Therefore,

$$\frac{\Gamma(\frac{n-1}{2})}{\Gamma(\frac{n-2}{2})\sqrt{\frac{n-1}{2}}}\left(\frac{\bar{x}}{s}\right)$$

is an unbiased estimator of

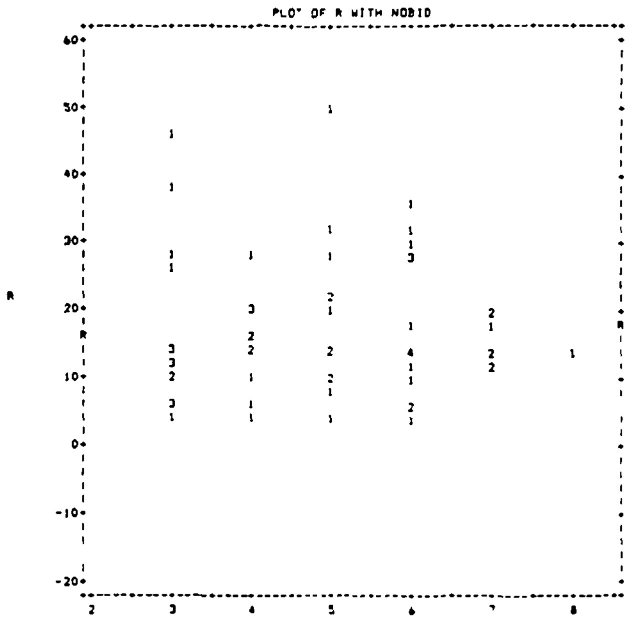
$$\frac{\mu}{\sigma}$$

(1, Cramer H., Mathematical methods of statistics, Princeton University Press, 1974)

APPENDIX I

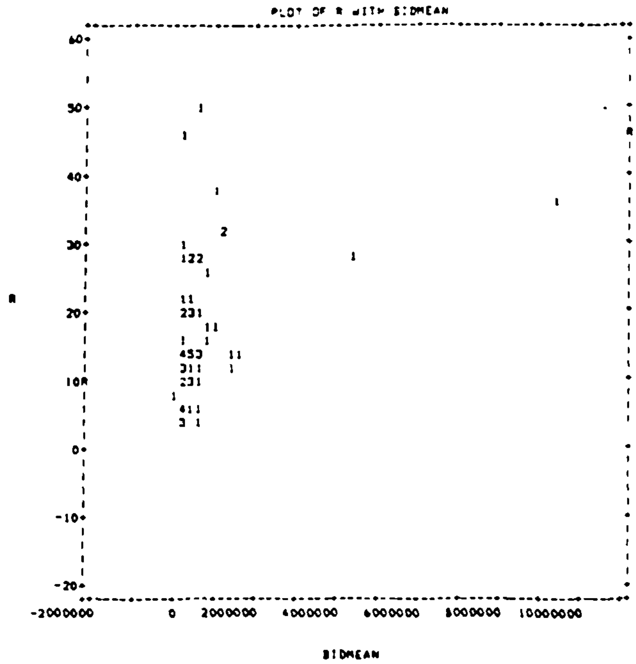
SCATTERPLOTS OF R, NUMBER OF BIDDERS AND BID MEAN FOR DIFFERENT JOB TYPES

18-Jan-90 Competitive Bidding for Refurbishment work   Page 49
12:07:40 Heriot-Watt University   on VAXA11   VMS V5.2



63 cases plotted. Regression statistics of R on NOBID:
Correlation .04745 R Squared .00225 S.E. of Est 10.12065 Sig. .7119
Intercept(S.E.) 15.56435 4.54056 Slope(S.E.) .33394(.90015)

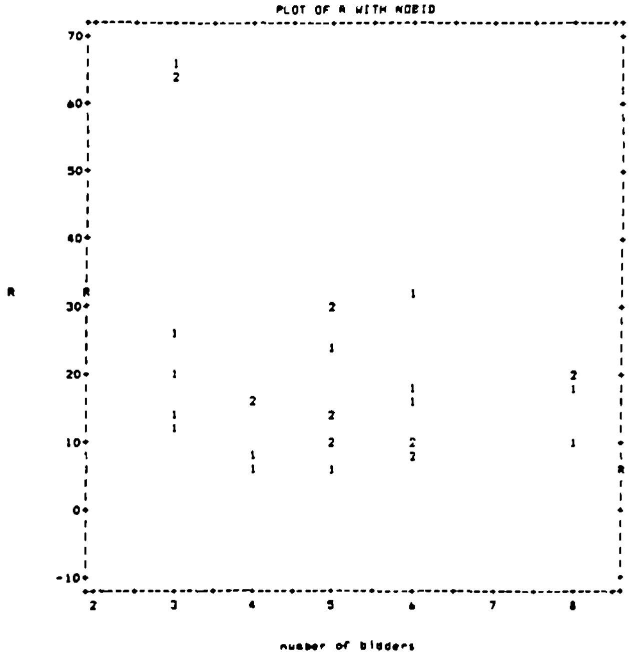
18-Jan-90 Competitive Bidding for Refurbishment work   Page 50
12:07:40 Heriot-Watt University   on VAXA11   VMS V5.2



63 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .34069 R Squared .11607 S.E. of Est 9.52593 Sig. .0063
Intercept(S.E.) 15.34626(1.36406) Slope(S.E.) .00000(.00000)

18-Jan-90 Competitive Bidding for Refurbishment work Page 52
12:07:40 Heriot-Watt University on VAXA:: VMS V5.2

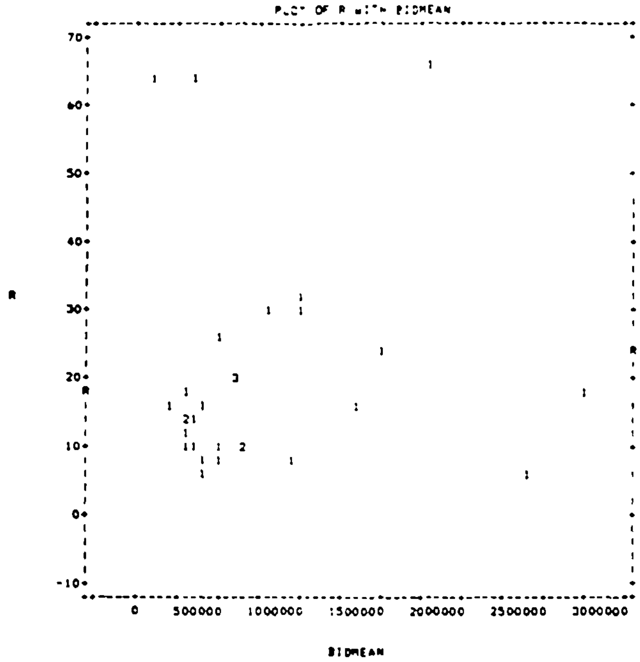
PLOT OF R WITH NOBID



30 cases plotted. Regression statistics of R on NOBID:
Correlation -.38324 R Squared .14687 S.E. of Est 15.55292 Sig. .0366
Intercept(S.E.) 40.41465 9.47677) Slope(S.E. -3.94387(1.79630)

18-Jan-90 Competitive Bidding for Refurbishment work Page 53
12:07:40 Heriot-Watt University on VAXA:: VMS V5.2

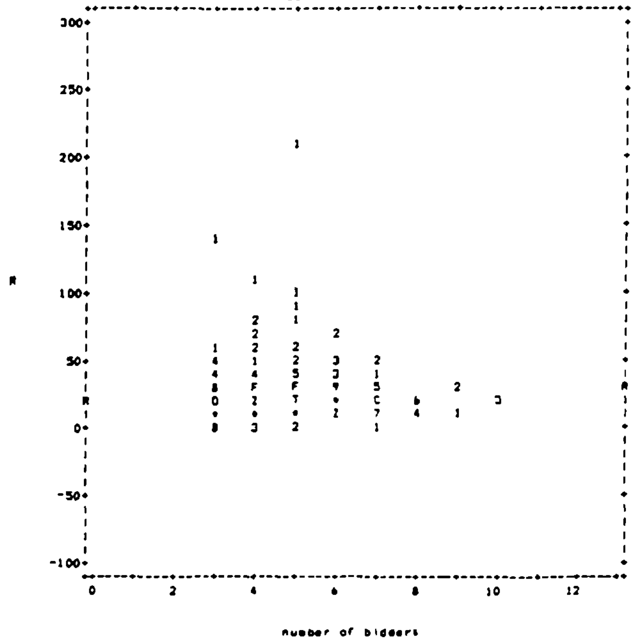
PLOT OF R WITH BIDMEAN



30 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .06832 R Squared 00467 S.E. of Est 16.79923 Sig. .7198
Intercept(S.E.) 19.25037(4.74830) Slope(S.E.) .00000(.00000)

18-Jan-90 Competitive Bidding for Refurbishment work Page 55
12:07:43 Heriot-Watt University on VAXA:: VMS V5.2

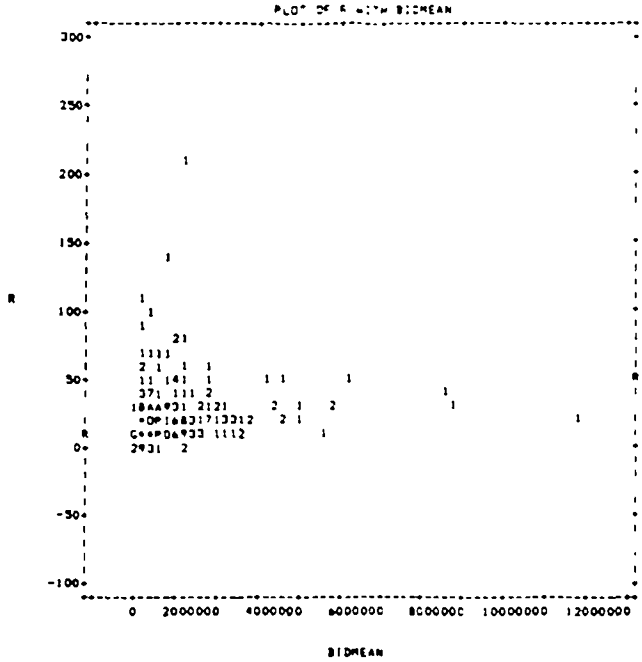
PLOT OF R WITH NOBID



468 cases plotted. Regression statistics of R on NOBID:
Correlation .05767 R Squared .00333 S.E. of Est 17.69044 Sig. .2131
Intercept(S.E.) 16.32225(2.87582) Slope(S.E.) .72704(.58307)

18-Jan-90 Competitive Bidding for Refurbishment work Page 56
12:07:43 Heriot-Watt University on VAXA:: VMS V5.2

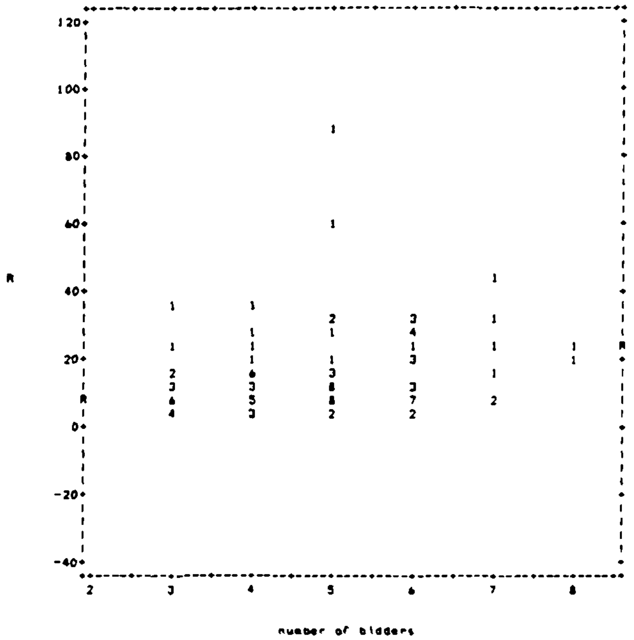
PLOT OF R WITH BIDMEAN



468 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .16096 R Squared .02591 S.E. of Est 17.48889 Sig. .0005
Intercept(S.E.) 17.65494(1.00555) Slope(S.E.) .00000(.00000)

18-Jan-90 Competitive Bidding for Refurbishment work Page 58
12:07:44 Heriot-Watt University on VAXA11 VMS V5.2

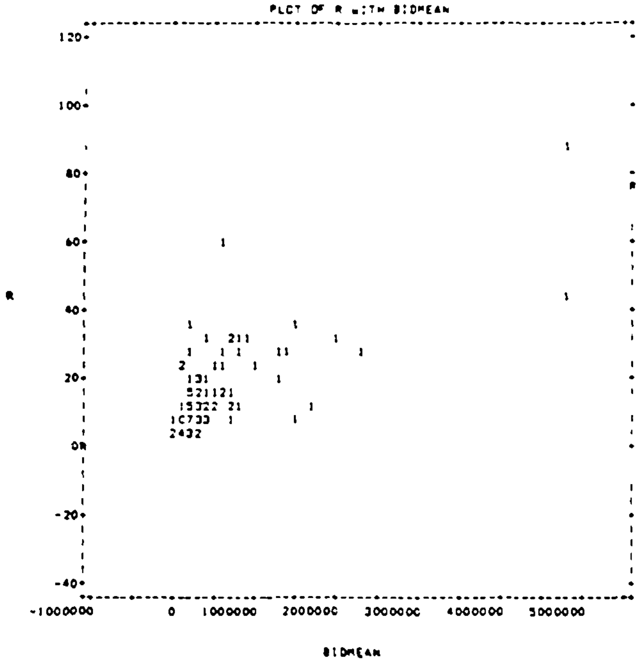
PLOT OF R WITH NOBID



96 cases plotted. Regression statistics of R on NOBID:
Correlation .22664 R Squared .05137 S.E. of Est 12.51746 Sig. .0264
Intercept(S.E.) 4.89270(5.09198) Slope(S.E.) 2.29092(1.01544)

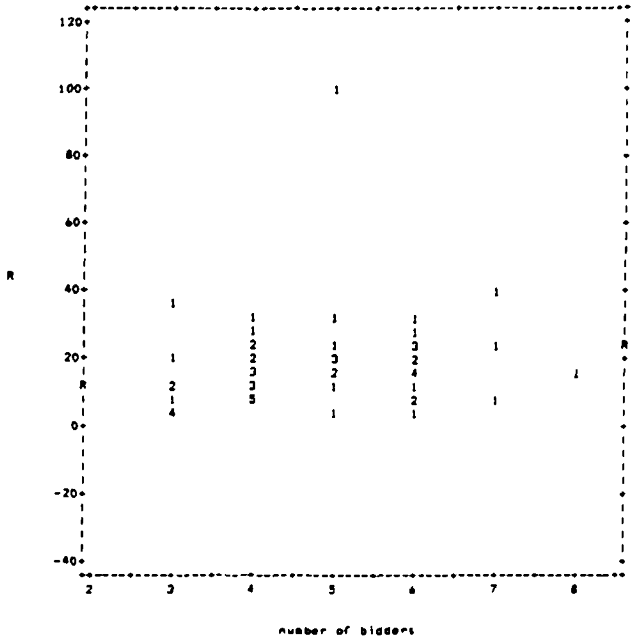
18-Jan-90 Competitive Bidding for Refurbishment work Page 59
12:07:44 Heriot-Watt University on VAXA11 VMS V5.2

PLOT OF R WITH BIDMEAN



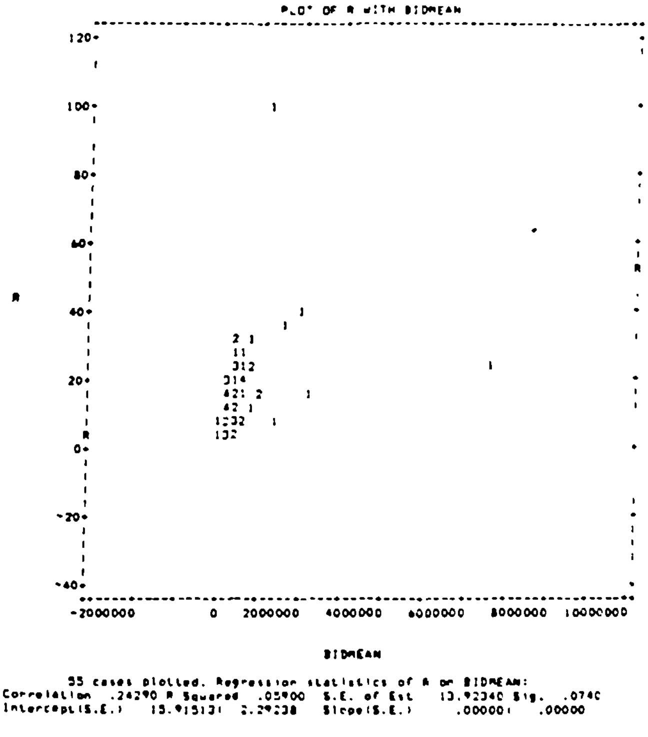
96 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .70245 R Squared .49344 S.E. of Est 9.14710 Sig. .0000
Intercept(S.E.) 9.89727(1.13140) Slope(S.E.) .00001(.00000)

PLOT OF R WITH NOBID



55 cases plotted. Regression statistics of R on NOBID:
Correlation .17663 R Squared .03120 S.E. of Est 14.12758 Sig. .1970
Intercept(S.E.) 8.80391(7.52378) Slope(S.E.) 1.98107 1.51638)

PLOT OF R WITH BIDMEAN



55 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .24290 R Squared .05900 S.E. of Est 13.92340 Sig. .0740
Intercept(S.E.) 15.91513(2.29238 Slope(S.E.) .00000(.00000

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18-Jan-90 Competitive Bidding for Refurbishment work                  Page  64
12:07:45  Heriot-Watt University          on VAXA::          VMS V5.2
```
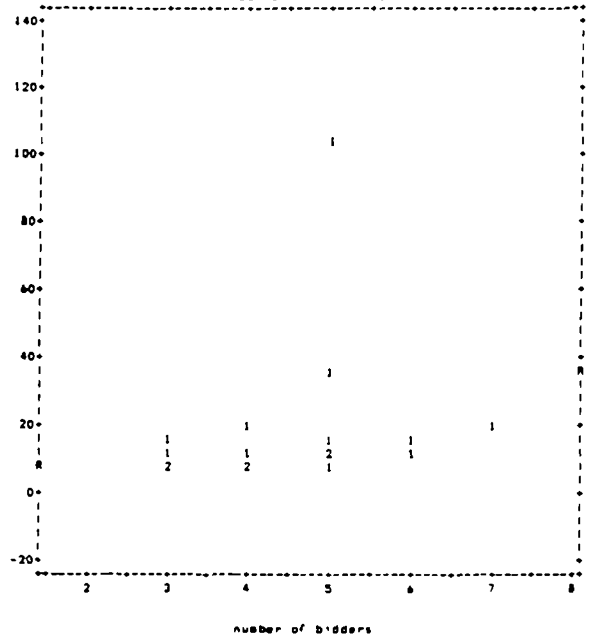
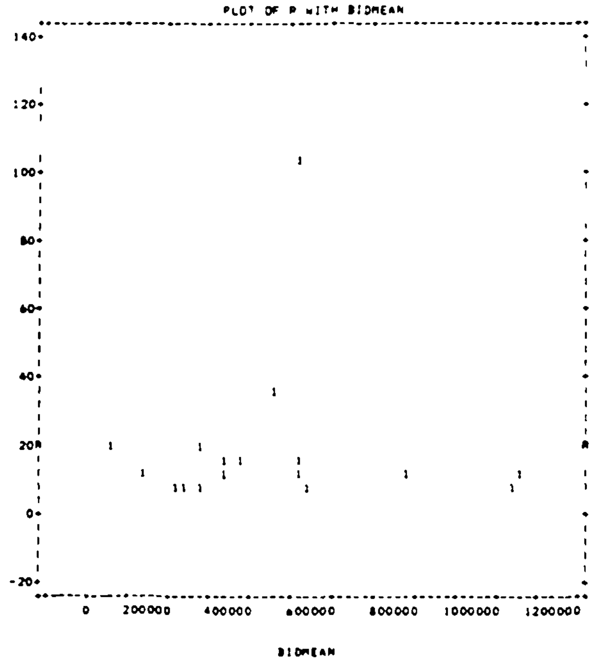

PLOT OF R WITH NOBID




```
        17 cases plotted. Regression statistics of R on NOBID:
Correlation  .21911 R Squared  .04801  S.E. of Est   23.19691 Sig.  .3981
Intercept(S.E.)     -.21235  22.98112)  Slope(S.E.)     4.27859(  4.91936)
```

```
18-Jan-90 Competitive Bidding for Refurbishment work                  Page  65
12:07:45  Heriot-Watt University          on VAXA::          VMS V5.2
```

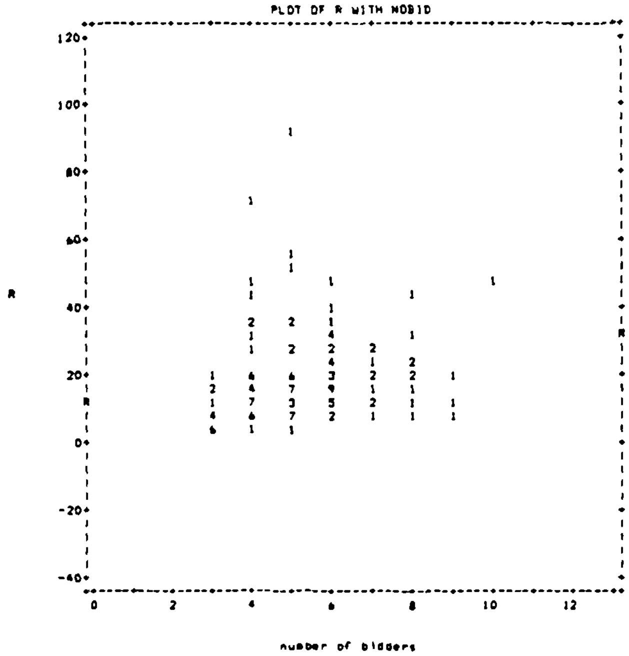
PLOT OF R WITH BIDMEAN




```
        17 cases plotted. Regression statistics of R on BIDMEAN:
Correlation -.00107 R Squared  .00000  S.E. of Est   23.77462 Sig.  .9967
Intercept(S.E.)   19.20696( 11.19661)  Slope(S.E.)      .00000(   .00002)
```

18-Jan-90 Competitive Bidding for Refurbishment work   Page 67
12:07:46 Heriot-Watt University   on VAXA::   VMS V5.2

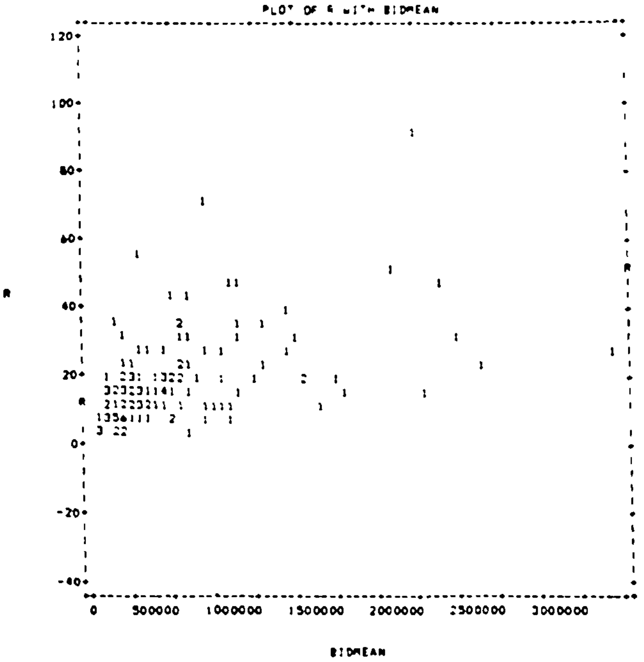
PLOT OF R WITH NOBID



130 cases plotted. Regression statistics of R on NOBID:
Correlation .17832 R Squared .03180 S.E. of Est 13.30905 Sig. .0424
Intercept(S.E.) 11.25343 4.21652 Slope(S.E.) 1.57660(.76894)

18-Jan-90 Compet t ve Bidding for Refurbishment work   Page 68
12:07:46 Heriot-Watt University   on VAXA::   VMS V5.2

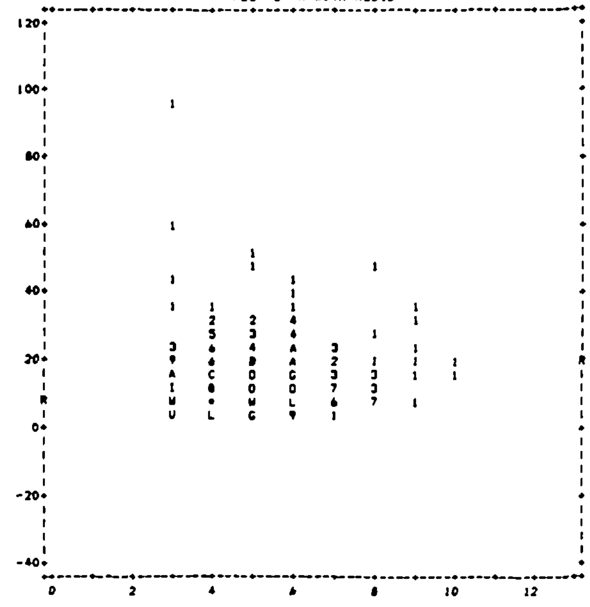
PLOT OF R WITH BIDMEAN



130 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .46935 R Squared .22029 S.E. of Est 11.94346 Sig. .0000
Intercept(S.E.) 13.11379(1.49890 Slope(S.E.) .00001(.00000)

18-Jan-90 Competitive Bidding for Refurbishment work Page 70
12:07:48 Heriot-Watt University on VAXA1: VMS V5.2

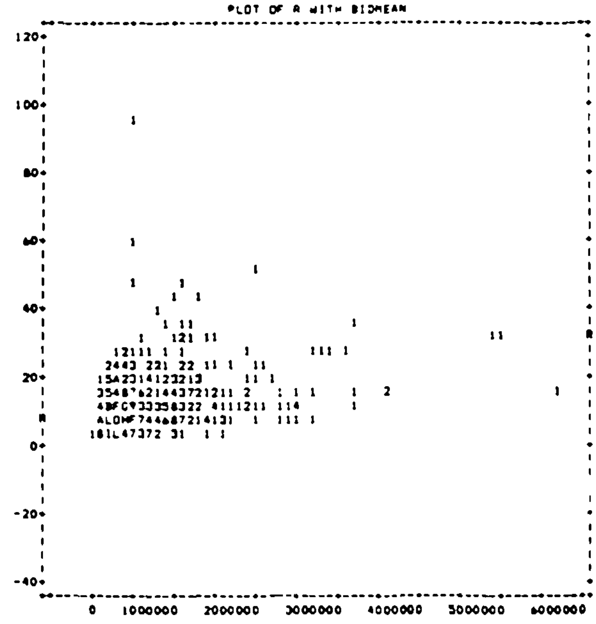
PLOT OF R WITH NOBID



491 cases plotted. Regression statistics of R on NOBID:
Correlation .16497 R Squared .02722 S.E. of Est 8.77436 Sig. .0002
Intercept(S.E.) 8.31703(1.38544) Slope(S.E.) 1.02603(.27739)

18-Jan-90 Competitive Bidding for Refurbishment work Page 71
12:07:49 Heriot-Watt University on VAXA1: VMS V5.2

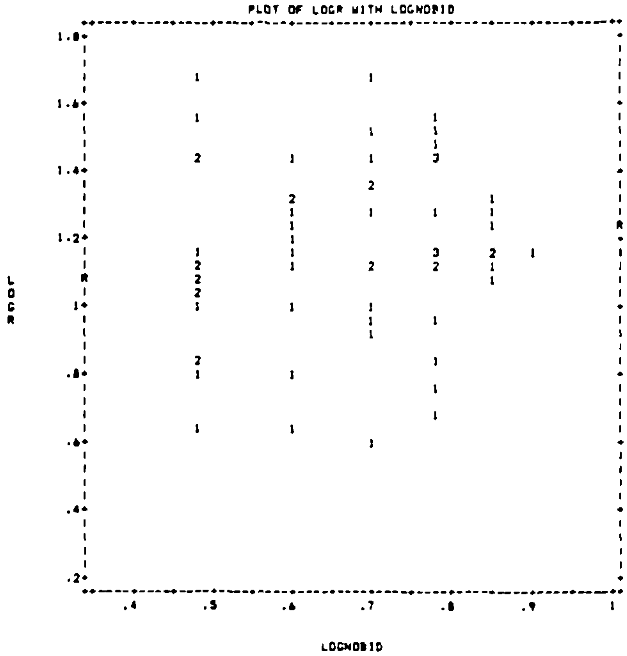
PLOT OF R WITH BIDMEAN



491 cases plotted. Regression statistics of R on BIDMEAN:
Correlation .26714 R Squared .07136 S.E. of Est 8.57295 Sig. .0000
Intercept(S.E.) 10.74509(.56010) Slope(S.E.) .00000(.00000)

18-Jan-90 Competitive Bidding for Refurbishment work Page 14
11:53:19 Heriot-Watt University on VAXA:: VMS V5.2

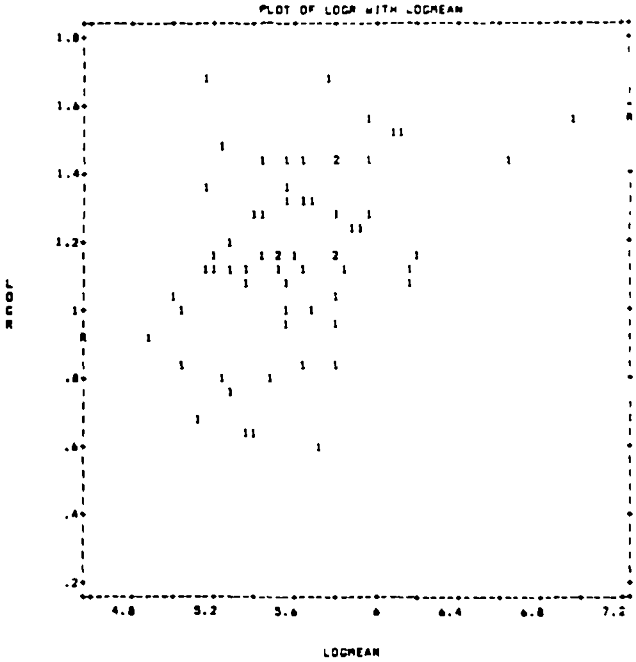
PLOT OF LOGR WITH LOGNOBID



63 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .11965 R Squared .01432 S.E. of Est .25773 Sig. .3503
Intercept(S.E.) 1.01027(.16590) Slope S.E.) .23018(.24454)

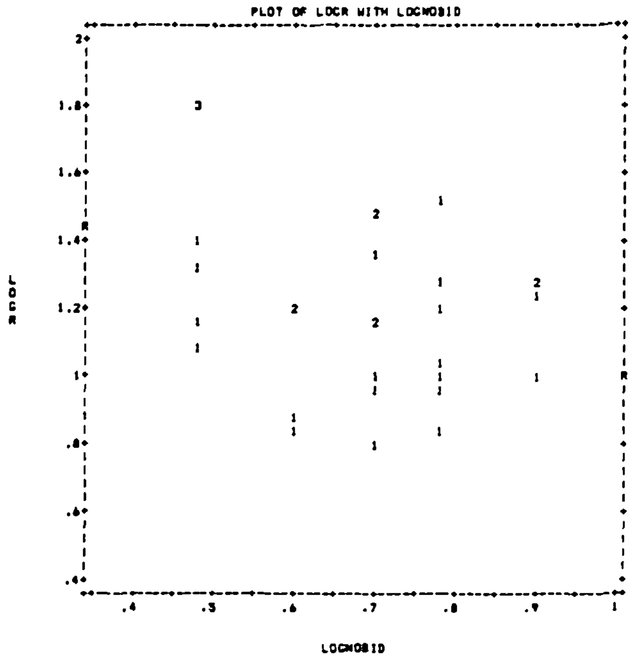
18-Jan-90 Competitive Bidding for Refurbishment work Page 15
11:53:20 Heriot-Watt University on VAXA:: VMS V5.2

PLOT OF LOGR WITH LOGMEAN



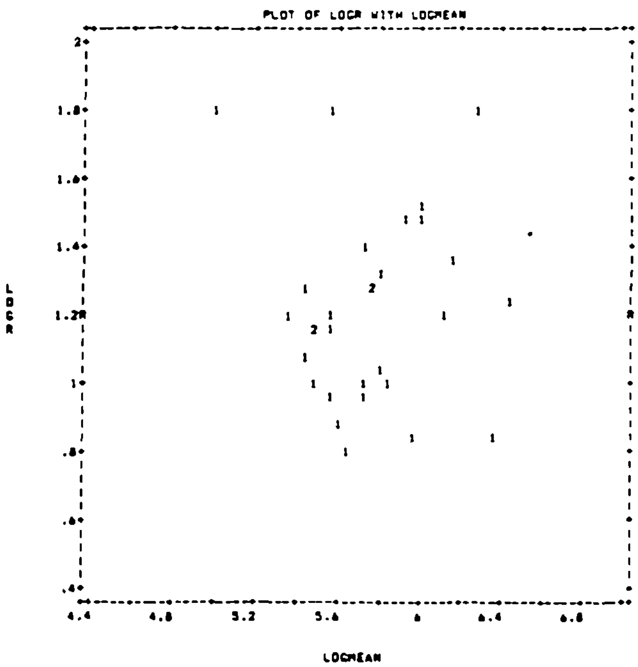
63 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation .38337 R Squared .14697 S.E. of Est .23976 Sig. .0019
Intercept(S.E.) -.28826(.44880) Slope(S.E.) .25903(.07990)

18-Jan-90 Competitive Bidding for Refurbishment work Page 18
11:53:31 Heriot-Watt University on VAXA11 VMS V5.2



30 cases plotted. Regression statistics of LOCR on LOGNOBID:
Correlation -.35128 R Squared .12340 S.E. of Est .26790 Sig. .0570
Intercept(S.E.) 1.68848(.24378) Slope(S.E.) -.69729(.35122)

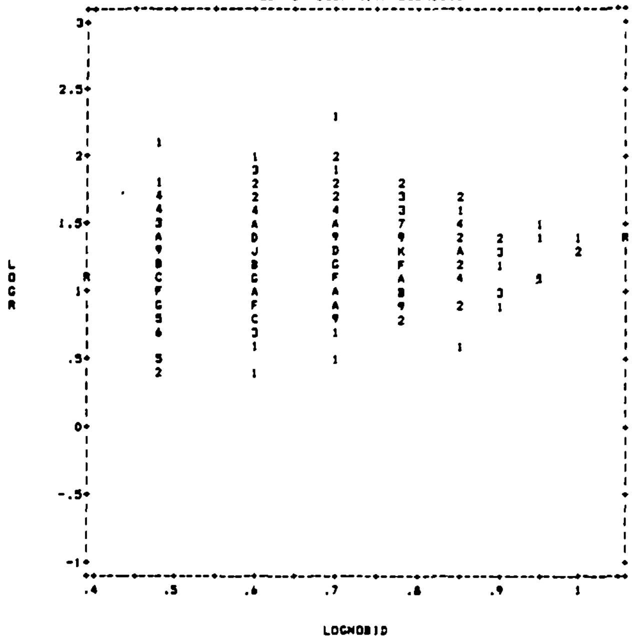
18-Jan-90 Competitive Bidding for Refurbishment work Page 19
11:53:31 Heriot-Watt University on VAXA11 VMS V5.2



30 cases plotted. Regression statistics of LOCR on LOCMEAN:
Correlation -.00343 R Squared .00001 S.E. of Est .28614 Sig. .9856
Intercept(S.E.) 1.23167(.95582) Slope(S.E.) -.00301(.16601)

18-Jan-90 Competitive Bidding for Refurbishment work Page 22
11:53:40 Heriot-Watt University on VAXA1: VMS V5.2

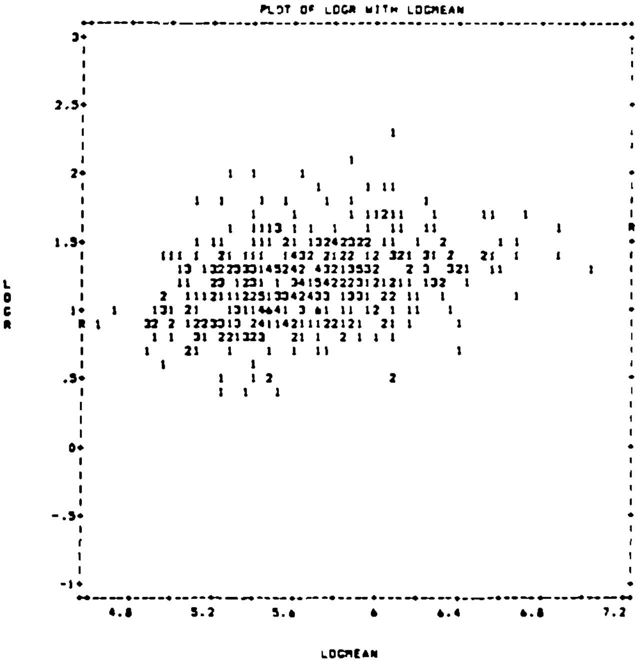
PLOT OF LOGR WITH LOGNOBID



468 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .17692 R Squared .03130 S.E. of Est .28588 Sig. .0001
Intercept(S.E.) .92344(.04989) Slope(S.E.) .40582(.10458)

18-Jan-90 Competitive Bidding for Refurbishment work Page 23
11:53:40 Heriot-Watt University on VAXA1: VMS V5.2

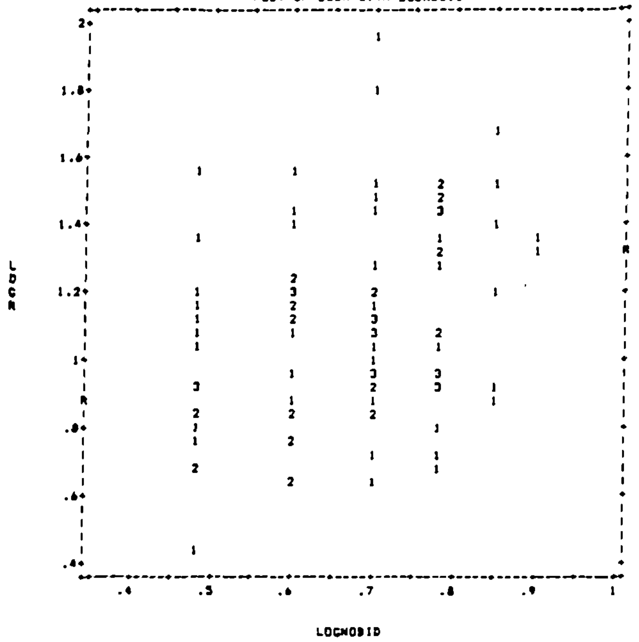
PLOT OF LOGR WITH LOGMEAN



468 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation .33216 R Squared .11033 S.E. of Est .27397 Sig. .0000
Intercept(S.E.) -.15831(.17805) Slope(S.E.) .23839(.03136)

18-Jan-90 Competitive Bidding for Refurbishment work   Page 26
11:53:53 Heriot-Watt University   on VAXA::   VMS V5.2

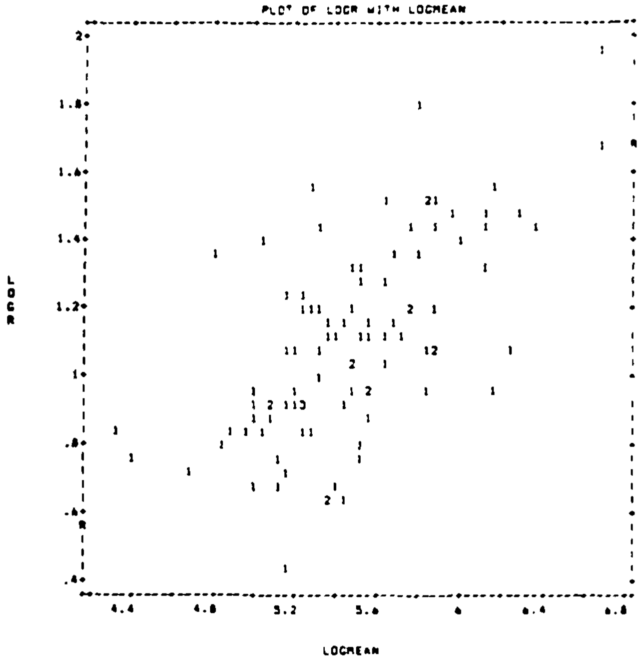
PLOT OF LOGR WITH LOGNOBID



96 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .29073 R Squared .08452 S.E. of Est .27628 Sig. .0041
Intercept(S.E.) .62849(.16415) Slope(S.E.) .71014(.24105)

18-Jan-90 Competitive Bidding for Refurbishment work   Page 27
11:53:53 Heriot-Watt University   on VAXA::   VMS V5.2

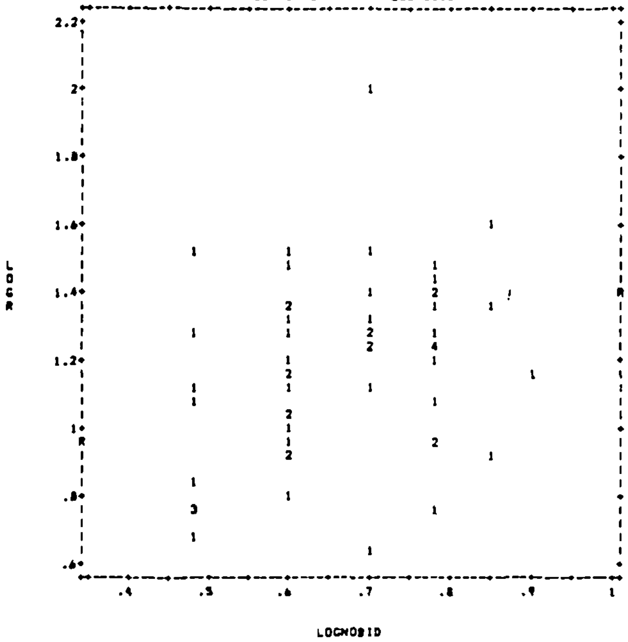
PLOT OF LOGR WITH LOGMEAN



96 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation .63366 R Squared .40153 S.E. of Est .22338 Sig. .0000
Intercept(S.E.) -1.20089(.29124) Slope(S.E.) .42082(.05299)

18-Jan-90 Competitive Bidding for Refurbishment work Page 30
11:54:04 Heriot-Watt University on VAXA11 VMS V5.2

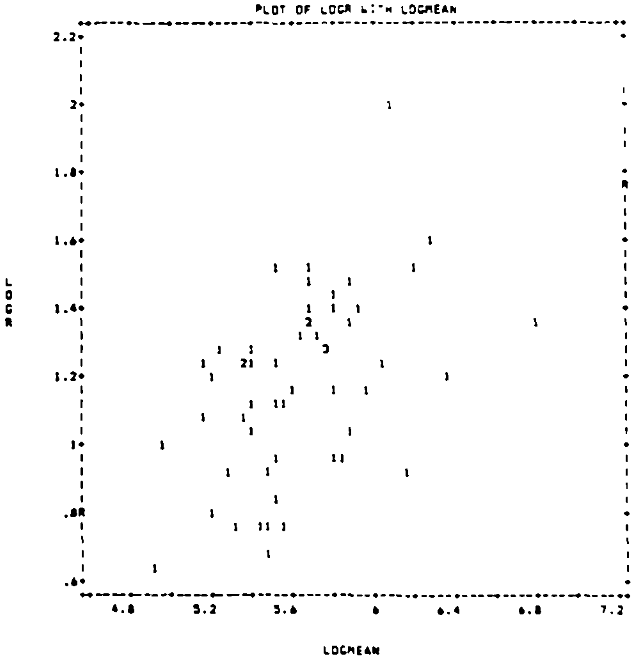
PLOT OF LOGR WITH LOGNOBID



55 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .31842 R Squared .10139 S.E. of Est .25339 Sig. .0178
Intercept(S.E.) .70048(.19879) Slope(S.E.) .71907(.29405)

18-Jan-90 Competitive Bidding for Refurbishment work Page 31
11:54:04 Heriot-Watt University on VAXA11 VMS V5.2

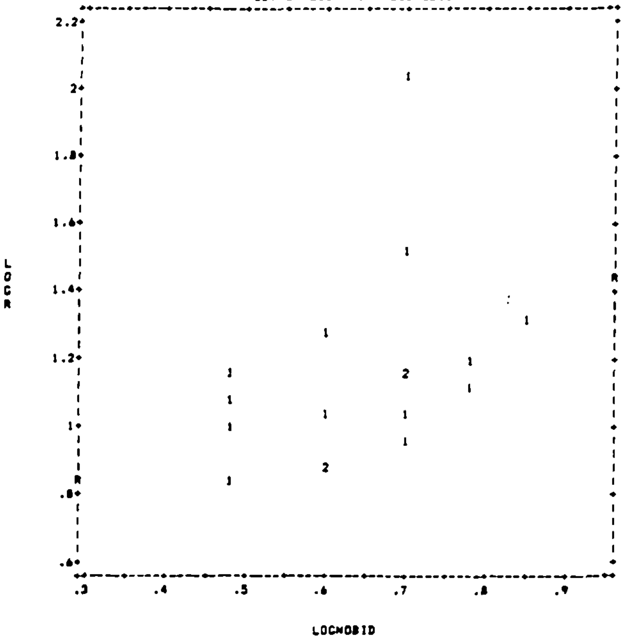
PLOT OF LOGR WITH LOGMEAN



55 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation .49222 R Squared .24228 S.E. of Est .23268 Sig. .0001
Intercept(S.E.) -.91694(.51019) Slope(S.E.) .37206(.09038)

18-Jan-90 Competitive Bidding for Refurbishment work Page 34
11:54:21 Heriot-Watt University on VAXA:: VMS V5.2

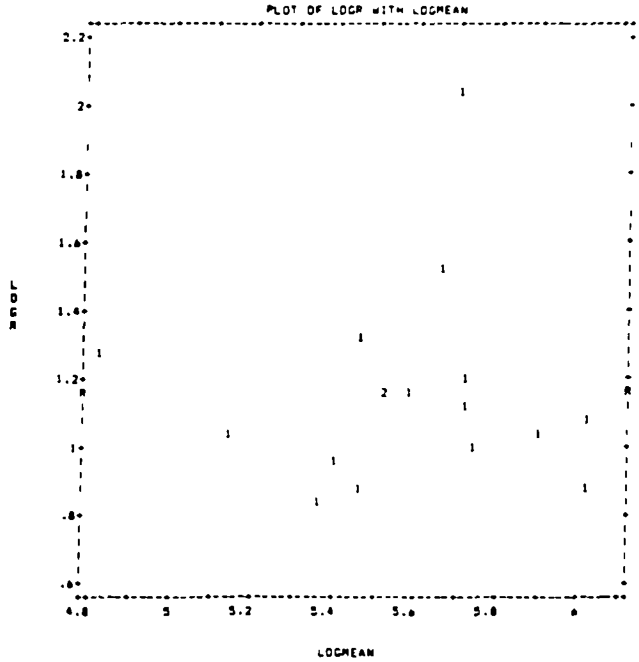
PLOT OF LOGR WITH LOGNOBID



17 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .39260 R Squared .15414 S.E. of Est .27040 Sig. .1190
Intercept(S.E.) .53339(.38181) Slope(S.E.) .96882(.58600)

18-Jan-90 Competitive Bidding for Refurbishment work Page 35
11:54:21 Heriot-Watt University on VAXA:: VMS V5.2

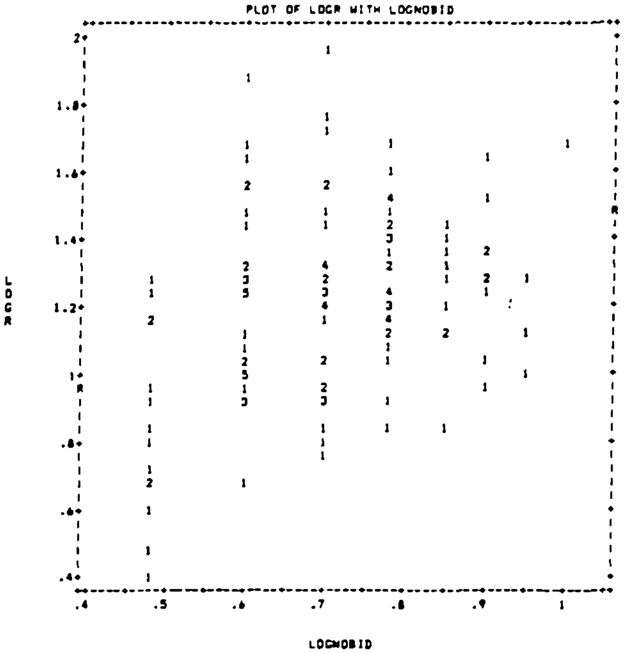
PLOT OF LOGR WITH LOGMEAN



17 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation -.00613 R Squared .00004 S.E. of Est .29400 Sig. .9814
Intercept(S.E.) 1.18735(1.35493) Slope(S.E.) -.00576(.24282)

18-Jan-90 Competitive Bidding for Refurbishment work Page 38
11:54:32 Heriot-Watt University on VAXA:: VMS V5.2

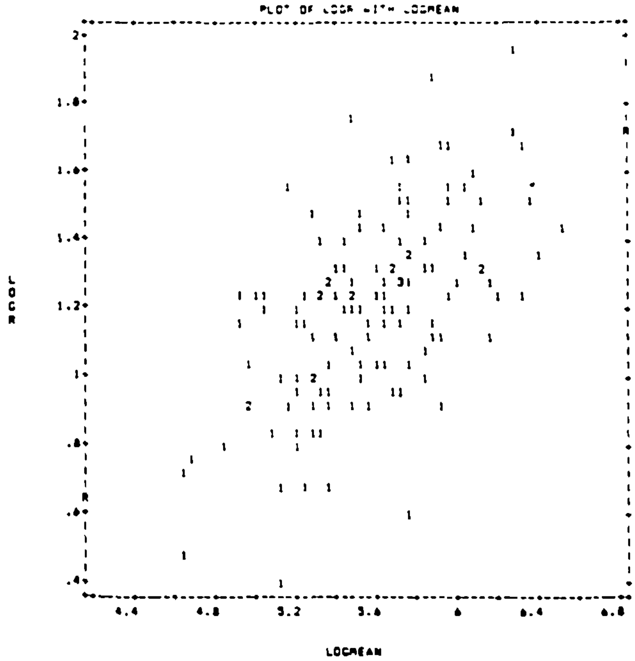
PLOT OF LOGR WITH LOGNOBID



130 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .34910 R Squared .12187 S.E. of Est .25911 Sig. .0000
Intercept(S.E.) .66683(.12999) Slope(S.E.) .76632(.18182)

18-Jan-90 Competitive Bidding for Refurbishment work Page 39
11:54:32 Heriot-Watt University on VAXA:: VMS V5.2

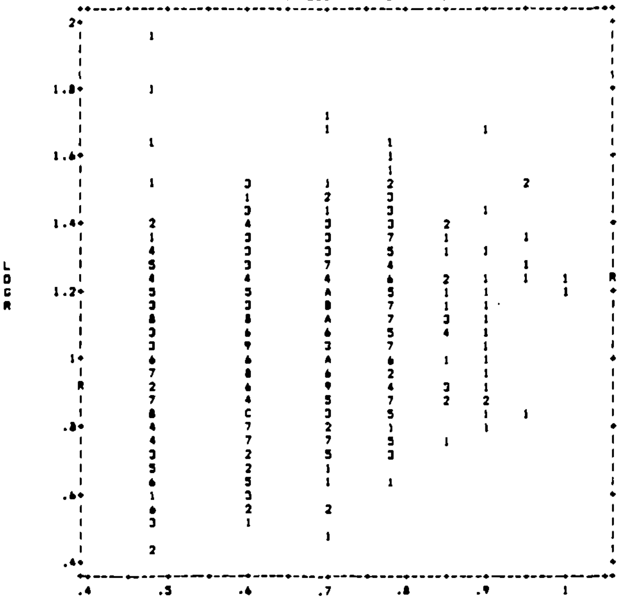
PLOT OF LOGR WITH LOGMEAN



130 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation .57835 R Squared .33449 S.E. of Est .22557 Sig. .0000
Intercept(S.E.) -1.09232(.28726) Slope(S.E.) .41249(.05143)

18-Jan-90 Competitive Bidding for Refurbishment work   Page 42
11:54:43 Heriot-Watt University   on VAXA11   VMS V5.2

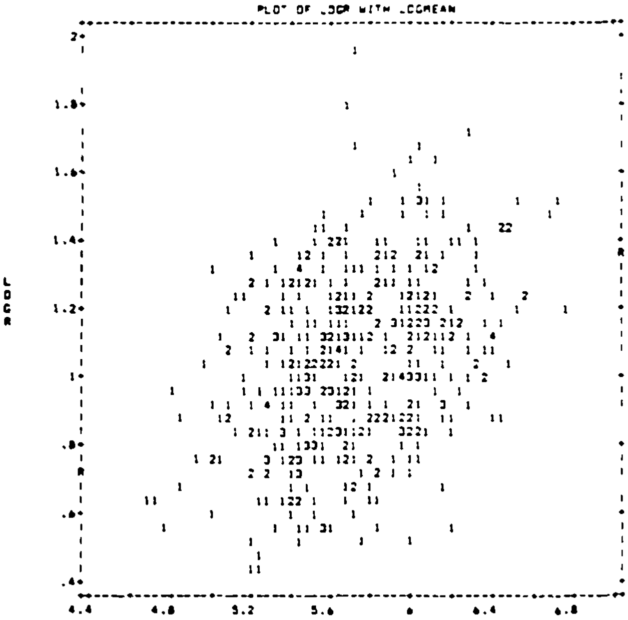
PLOT OF LOGR WITH LOGNOBID



491 cases plotted. Regression statistics of LOGR on LOGNOBID:
Correlation .24824 R Squared .06162 S.E. of Est .24633 Sig. .0000
Intercept(S.E.) .71876(.05870) Slope(S.E.) .49396(.08717)

18-Jan-90 Competitive Bidding for Refurbishment work   Page 43
11:54:44 Heriot-Watt University   on VAXA11   VMS V5.2

PLOT OF LOGR WITH LOGMEAN



491 cases plotted. Regression statistics of LOGR on LOGMEAN:
Correlation .35423 R Squared .12548 S.E. of Est .23781 Sig. .0000
Intercept(S.E.) -.34474(.16631) Slope(S.E.) .24283(.02899)

APPENDIX J

STEPWISE REGRESSION FOR LOG R FOR DIFFERENT JOB TYPES

1) Transport and Utility

```
        ****  M U L T I P L E   R E G R E S S I O N  ****

Listwise Deletion of Missing Data
Equation Number 1    Dependent Variable..   LOGR

 Beginning Block Number  1.  Method:  Stepwise

 Variable(s) Entered on Step Number
    1..     LOGMEAN

 Multiple R            .38337
 R Square              .14697
 Adjusted R Square     .13299
 Standard Error        .23976

 Analysis of Variance
                      DF      Sum of Squares      Mean Square
 Regression            1              .60416           .60416
 Residual             61             3.50661           .05748

 F =       10 51006        Signif F =  .0019


------------------ Variables in the Equation ------------------
Variable                B         SE B        Beta          T  Sig T

 LOGMEAN           259033       079901     .383371      3.242   0019
 (Constant)       - 288264      .448798                 - 642  .5231


End Block Number   1   POUT =       100 Limits reached.
```

2) Office and administration

```
        ****  M U L T I P L E   R E G R E S S I O N  ****

Listwise Deletion of Missing Data
Equation Number 1    Dependent Variable.    LOGR

 Beginning Block Number  1   Method   Stepwise

 Variable(s) Entered on Step Number
    1.     LOGMEAN

 Multiple R            33216
 R Square              11033
 Adjusted R Square     10842
 Standard Error        27397

 Analysis of Variance
                      DF      Sum of Squares      Mean Square
 Regression            1             4 33782          4 33782
 Residual            466            34 97871            07506

 F =      57 "9016        Signif F =   0000


------------------ Variables in the Equation ------------------
Variable                B         SE B        Beta          T  Sig T

 LOGMEAN           238392       031359      332161      7.602   0000
 (Constant)       - 158314      178047                  -.889   3744


End Block Number   1   POUT =       100 Limits reached.
```

3) Health and welfare

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data
Equation Number 1   Dependent Variable..   LOGR

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number
1..   LOGMEAN

Multiple R	.63366
R Square	.40153
Adjusted R Square	.39516
Standard Error	.22338

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	3.14694	3.14694
Residual	94	4.69042	.04990

F = 63.06742   Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
LOGMEAN	.420818	.052990	.633666	7.941	.0000
(Constant)	-1.200892	.291239		-4.123	.0001

End Block Number 1   POUT = .100 Limits reached.

4) Recreation, refreshment and entertainment

**** MULTIPLE REGRESSION ***

Listwise Deletion of Missing Data
Equation Number 1   Dependent Variable..   LOGR

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number
1..   LOGMEAN

Multiple R	.49222
R Square	.24228
Adjusted R Square	.22799
Standard Error	.23268

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	.91747	.91747
Residual	53	2.86932	.05414

F = 16.94692   Signif F = .0001

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
LOGMEAN	.372062	.090380	.492222	4.117	.0001
(Constant)	-.916944	.510193		-1.797	.0780

End Block Number 1   POUT = .100 Limits reached.

5) Education, scientific and information

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data
Equation Number 1   Dependent Variable.. LOGR

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number
1.. LOGMEAN

Multiple R	.57835
R Square	.33449
Adjusted R Square	.32929
Standard Error	.22567

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	3.27347	3.27347
Residual	128	6.51296	.05088

F = 64.33384   Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
LOGMEAN	.412490	.051427	.578352	8.021	.0000
(Constant)	-1.092324	.287258		-3.803	.0002

End Block Number 1   POUT = .100 Limits reached.

6) Residential

**** MULTIPLE REGRESSION ***

Listwise Deletion of Missing Data
Equation Number 1   Dependent Variable.. LOGR

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number
1.. LOGMEAN

Multiple R	.35423
R Square	.12548
Adjusted R Square	.12369
Standard Error	.23781

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	3.96772	3.96772
Residual	489	27.65367	.05655

F = 70.16130   Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
LOGMEAN	.242827	.028990	.354226	8.376	.0000
(Constant)	-.344744	.166307		-2.073	.0387

End Block Number 1   POUT = .100 Limits reached.

APPENDIX K

TABLE OF K VALUES FOR NORAML AND EDGEWORTH DISTRIBUTION

(i) k values of Edgeworth distribution

NUMBER OF BIDDERS	PROBABILITY OF SUCCESS				
	0.1	0.2	0.3	0.4	0.5
2	0.46797	0.12011	-0.13224	-0.34918	-0.55326
3	0.07730	-0.22602	-0.44808	-0.64045	-0.82272
4	-0.16906	-0.44620	-0.65035	-0.82812	-0.99737
5	-0.34525	-0.60461	-0.79658	-0.96437	-1.12469
6	-0.48064	-0.72693	-0.90989	-1.07029	-1.22398
7	-0.58966	-0.82580	-1.00174	-1.15638	-1.30487
8	-0.68037	-0.90832	-1.07859	-1.22856	-1.37283
9	-0.75771	-0.97886	-1.14442	-1.29049	-1.43125
10	-0.82487	-1.04027	-1.20183	-1.34459	-1.48235

NUMBER OF BIDDERS	PROBABILITY OF SUCCESS			
	0.6	0.7	0.8	0.9
2	-0.75879	-0.98048	-1.24248	-1.61067
3	-1.00761	-1.20860	-1.44826	-1.78892
4	-1.16988	-1.35837	-1.58443	-1.90816
5	-1.28868	-1.46852	-1.68513	-1.99697
6	-1.38162	-1.55499	-1.76449	-2.06735
7	-1.45753	-1.62581	-1.82970	-2.12542
8	-1.52143	-1.68557	-1.88486	-2.17472
9	-1.57646	-1.73712	-1.93254	-2.21746
10	-1.62467	-1.78235	-1.97446	-2.25512

(ii) **k values of Normal distribution**

NUMBER OF BIDDERS	PROBABILITY OF SUCCESS				
	0.1	0.2	0.3	0.4	0.5
2	0.47827	0.13270	-0.11991	-0.33836	-0.54495
3	0.08996	-0.21420	-0.43835	-0.63353	-0.81933
4	-0.15691	-0.43644	-0.64360	-0.82485	-0.99815
5	-0.33439	-0.59710	-0.79263	-0.96430	-1.12900
6	-0.47132	-0.72158	-0.90848	-1.07304	-1.23132
7	-0.58191	-0.82248	-1.00264	-1.16163	-1.31487
8	-0.67416	-0.90688	-1.08158	-1.23605	-1.38520
9	-0.75296	-0.97917	-1.14932	-1.30001	-1.44574
10	-0.82153	-1.04220	-1.20848	-1.35596	-1.49877

NUMBER OF BIDDERS	PROBABILITY OF SUCCESS			
	0.6	0.7	0.8	0.9
2	-0.75407	-0.98082	-1.25042	-1.63222
3	-1.00867	-1.21546	-1.46338	-1.81828
4	-1.17555	-1.37022	-1.60490	-1.94320
5	-1.29814	-1.48441	-1.70984	-2.03647
6	-1.39430	-1.57426	-1.79274	-2.11052
7	-1.47300	-1.64799	-1.86096	-2.17171
8	-1.53937	-1.71030	-1.91876	-2.22372
9	-1.59660	-1.76412	-1.96879	-2.26886
10	-1.64680	-1.81141	-2.01281	-2.30868